THE INSTITUTE OF PHYSICS

BULLETIN

CONTENTS

Methodology and Aesthetic Content in Natural Science . . . . . F. I. G. RAWLINS 205

The Qualities of a Good Science Teacher CYRIL BIBBY 210

Notes and News 215

Reviews of Books 216

Group News 221

Forthcoming Institute Meetings 222

The Register 226

The Graduateship Examination 1959 228

Papers set in the Graduateship Examination 1959 229

Comments by the Examiners 253

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

D.S.I.R. ROAD RESEARCH LABORATORY (Traffic and Safety Division), Langley, Bucks., requires SCIENTIFIC OFFICERS / SENIOR SCIENTIFIC OFFICERS for work on one or more of the following : Planning of sampling surveys ; Theoretical aspects of traffic flow ; Application of electronic computers to traffic and safety matters ; Application of traffic engineering principles to solution of traffic problems ; Development of electronic and other equipment for experimental use in vehicles ; Experimental and theoretical investigations into accidents ; Relationships between injuries and vehicle design. Qualifications : 1st or 2nd class honours degree or equivalent qualifications in physics, mathematics, statistics or civil and mechanical engineering. At least three years' postgraduate experience for Senior Scientific Officer. Salary : Scientific Officer £635 – £1,120 (with allowance for postgraduate experience and National Service), Senior Scientific Officer : £1,200 – £1,420. Equal pay scheme. Normal prospects of promotion in mid-thirties to Principal Scientific Officer (£1,460 – £2,070) with possibilities of higher posts. Forms from M.L.N.S. Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting reference A.254/9A.

SHELL

SHELL REFINING COMPANY LTD.

require a

Physicist

at their

STANLOW REFINERY,
near **CHESTER**

This is a semi-specialist appointment initially, as the successful applicant will be expected to progress towards senior positions in general plant operation and technological work. All necessary training will be given in techniques special to the industry.

Candidates should be up to 30 years of age and possess an Honours Degree or Ph.D. from a U.K. University.

Salary according to age, qualifications and experience. Attractive Pension Scheme.

Applications with full details to :

Shell Refining Company Ltd.
Staff Department
Clements House,
14/18 Gresham Street, London,
E.C.2.

CITY OF BIRMINGHAM
EDUCATION COMMITTEE
ASTON TECHNICAL COLLEGE
WHITEHEAD ROAD, BIRMINGHAM, 6
Principal : D. Dudgeon Stockley, B.Sc., M.I.Mech.E.

ASSISTANT, GRADE B, required on January 1, 1960, to teach physics to G.C.E. advanced level and in O.N.C. (chemistry) courses, and have some mathematics or chemistry. Candidates should have a degree or an equivalent qualification.

Present salary scale £682 10s. 0d. × £26 5s. 0d. – £1,076 5s. 0d. (An improved salary scale as from October 1, 1959, is under consideration). Additional increments above the minimum of the scale may be granted for time spent in industry, commerce, professional work or research. There are also additions to the scale for degree or for equivalent professional qualifications. Application form and further details may be obtained from the Principal and should be returned to him within 14 days of the appearance of this advertisement.

E. L. Russell, Chief Education Officer.

THE ROYAL COLLEGE OF
SCIENCE AND TECHNOLOGY
GLASGOW
(Affiliated to the University of Glasgow)

ASSISTANT LECTURER. Applications are invited for the above post in Department of Natural Philosophy from candidates with good degree and, advantageously, with postgraduate experience. Salary scale £700 × £50 – £850 with F.S.S.U. and family allowances. Application forms may be had from the Secretary.

CHELSEA COLLEGE OF SCIENCE
AND TECHNOLOGY
SESSION 1959-60
DEPARTMENT OF PHYSICS

POSTGRADUATE COURSES, full and part-time : The following courses begin during week commencing October 5, 1959 : acoustics and vibration physics, optics, nuclear physics, quantum mechanics, semiconductors, electromagnetism, physical electronics, electronic circuits. Suitably qualified students may register as M.Sc. Internal students of the University of London.

DEGREE COURSES, full-time and " Sandwich " : These courses, for special and general honours degrees of the University of London, begin on September 28, 1959. For students engaged in industry, the sandwich course has been planned as an alternative part-time course in which students attend for two terms full-time and one term part-time in each of four sessions.

Details and application forms may be obtained from The Secretary, Physics Dept., Chelsea College of Science and Technology, London, S.W.3. Flaxman 5747.

GEOPHYSICISTS

BP requires Geophysicists for World Wide Service. Candidates must be graduates in physics, geology or mathematics. Commencing basic salary is commensurate with qualifications, age and experience, appropriate allowances are paid on foreign service. Kit allowance, pension scheme, good leave arrangements, free medical attention. Written application, quoting reference F.569, should be addressed to The Manager, Recruitment Branch, The British Petroleum Co. Ltd., BP House, Ropemaker Street, London, E.C.2.

UNIVERSITY OF TASMANIA
CHAIR OF PHYSICS

The University invites applications for appointment to the Chair of Physics which will become vacant next October on the retirement, owing to ill-health, of Professor A. L. McAulay, B.Sc., M.A., Ph.D., F.Inst.P. The salary payable is £A3,500 per annum. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in Australia and London, on October 15, 1959.

BRITISH
SCIENTIFIC INSTRUMENT
RESEARCH ASSOCIATION

◆

PHYSICIST, with good degree, required for interesting work on scintillation detecting elements and other aspects of nucleonic work. Some knowledge of electronic techniques desirable. Laboratories in pleasant rural surroundings within easy reach of London. Liberal holidays and F.S.S.U. benefits. Appointment initially in the Scientist grade (£620–£1,035 p.a.) with good prospects.

Applications to the Director :

J. Thomson, D.Sc., B.S.I.R.A.,
South Hill, Chislehurst, Kent,
quoting reference TPF.

JOSEPH LUCAS LTD.

GROUP RESEARCH CENTRE

* * *

There are vacancies in the Department of Physics, situated at Marston Green, Birmingham, for men of good academic background and outstanding technical ability as follows :

METALLURGIST to work on the preparation and analysis of the structure of semi-conducting compounds. Candidates must have an honours degree in Metallurgy with preferably a higher degree or equivalent technical experience.

PHYSICIST to specialize in solid state physics. Candidates must have an honours degree in Theoretical Physics and preferably a higher degree.

PHYSICIST to specialize in solid state physics. Candidates must have an honours degree in Physics.

PHYSICIST to specialize in rating semiconductor devices and design of electronic test equipment. Candidates should have a degree in Physics or equivalent technical qualifications and experience.

TECHNOLOGIST to work on the design and fabrication of silicon transistors and control rectifiers. Candidates must have all round ability.

PHYSICIST to specialize in work on the friction of materials on hard surfaces. Candidates must have an honours degree in Physics with preferably a higher degree or equivalent technical experience.

The appointments are permanent and pensionable and a good starting salary will be paid. Apply in writing giving full details of age, qualifications and experience to the

Personnel Manager
Joseph Lucas (Electrical) Ltd.
Great King Street
Birmingham, 19

quoting reference PM/GR/281.

THE HOSIERY AND ALLIED TRADES RESEARCH ASSOCIATION
DIRECTOR OF RESEARCH

The Council of the Hosiery and Allied Trades Research Association invite applications for the post of Director of Research, to take up his duties as soon as possible at their laboratories in Nottingham. There is a staff of 73 of whom 14 are science graduates and qualified textile technologists. The Association, which is financed by voluntary subscriptions from the Hosiery and Allied Trades and by grant aid from the D.S.I.R. was established in 1949. The Director of Research is the chief executive of the Association and must possess suitable scientific and technological qualifications with powers of leadership and experience of research administration. Salary, in accordance with qualifications and experience, will be substantial and the appointment will carry superannuation under the F.S.S.U. Scheme. Applications should be sent to the Chairman, The Hosiery and Allied Trades Research Association, Thorneywood, 7 Gregory Boulevard, Nottingham.

ELECTRONICS ENGINEER OR PHYSICIST required by Aluminium Laboratories Ltd., to design equipment for inspection of aluminium products (eddy current, ultrasonics, etc.). Pension and Life Assurance Scheme in operation. Apply Personnel Officer, Southam Road, Banbury, Oxon.

PHYSICIST required to investigate problems arising in the protection of packaged goods against impact and vibration. Initially the work will be on the properties of materials under impact conditions, but will extend to the response of structures to pulse loading and the dynamics of a complete package. Mathematical ability will be necessary, and experience in electronics and in the mathematical techniques required, would be desirable. Salary on scale £650 – £1,150 according to qualifications and experience. F.S.S.U. 5-day week. Candidates with a good honours degree should apply in writing to the Secretary, The Printing, Packaging and Allied Trades Research Association, Randalls Road, Leatherhead, Surrey, for an application form. Please quote : Physicist 8/59.

RHODES UNIVERSITY
GRAHAMSTOWN, SOUTH AFRICA

Applications are invited for the posts of: SENIOR LECTURER IN PHYSICS, LECTURER IN PHYSICS from January, 1960. The salary scales are : Senior Lecturer : £1,530 × £60 – £1,950 p.a. Lecturer : £1,050 × £60 – £1,530 p.a. Previous experience and academic qualifications may be taken into account in fixing the commencing salary. Full particulars and application forms may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in South Africa and London, on September 30, 1959.

SHELL

"Shell" Research Ltd.

require an

Experimental Physicist

A graduate with experimental skill above average is required for instrument development. He should have a keen interest in measuring techniques.

Applicants with lower academic qualifications but with sutiable experience and interests will be considered.

The post is at
Thornton Research Centre
near Chester

Five-day week ; attractive pension scheme ; removal expenses from established home and help with housing for successful applicant.

Applications should be made to :

Personnel Recruitment P/E.,
" Shell " Research Ltd.,
St. Helen's Court,
Great St. Helen's, London,
E.C.3.

RESEARCH PHYSICIST

The physics of thin film deposition by the high vacuum method is being studied at the British Scientific Instrument Research Association. Physicists wishing to carry out research of this basic nature are invited to apply to the Director for a post, giving full details of their career and qualifications. The salary will be not less than £900 and will depend mainly on the qualifications (including experience in research) of the successful applicant.

The laboratories are very pleasantly situated in rural surroundings, 30 minutes by train from Charing Cross. Free meals are available on the premises.

Address :

British Scientific Instrument
Research Association,
South Hill,
Chislehurst, Kent.

CENTRAL ELECTRICITY GENERATING BOARD

Southern, South Western and South Wales Region

PHYSICISTS AND RESEARCH ENGINEERS

(Research and Development)

Physicists and Research Engineers with good honours degrees are required in the Regional Research and Development Department.

The duties at Senior Levels will include the assessment, initiation and supervision of research and development on the wide range of problems arising from the economic operation of Power Station Plant. The duties at other levels will be the carrying out of research and development in the laboratories and on the above plant within the Region. Applicants with experience in **Combustion Research** are particularly required.

The salary for the appointments will be on the scales within the overall ranges £1,365 – £1,865 per annum, £1,090 – £1,445 per annum and £735 – £1,170 per annum according to duties and responsibilities. House purchase loan assistance and a grant of up to 75% of the legal expenses of house purchase, subject to a maximum of £125, are available.

Applications on form AE6/ACT augmented by any additional information thought necessary and accompanied, where possible, by copies of two recent reports on original research should be addressed to :

The Regional Secretary, Central Electricity Generating Board,
Southern, South Western and South Wales Region, 1 Eaton Crescent, Bristol, 8,
so as to arrive not later than first post on Wednesday, September 30, 1959.

PHYSICS AS A CAREER

By Norman Clarke

Second (revised) edition

To be published on September 30 by Chapman & Hall Ltd., on behalf of The Institute of Physics

See page 215 of this issue of the " Bulletin "

Order form for members of the Institute (all grades)

To: The Secretary, The Institute of Physics,
47 Belgrave Square, London, S.W.1.

Please supply one copy of *Physics as a Career* for my personal use, at the special members' rate of 6s. 6d. A remittance is enclosed.

Name and mode of address ....
(BLOCK CAPITALS)

Address ....

....

Grade in Institute ....

Date ....

Signed ....

NATIONAL COLLEGE OF FOOD TECHNOLOGY

St. George's Avenue, Weybridge
Surrey

Principal : J. D. Mounfield, M.Sc.Tech., Ph.D., F.R.I.C.

Applications are invited for the post of ASSISTANT LECTURER in the College from Graduates in physics or engineering. Special consideration will be given to applicants with experience in industrial engineering. The new College will come into use in October this year and the candidate appointed will be expected to assist with the development of the courses there. New laboratories will provide facilities for original work.

Salary scale : £813 15s. × £26 5s. to £1,207 10s. plus an appropriate increase from October 1, 1959, in accordance with the recent Burnham Committee award. The starting salary will be dependent on qualifications and experience. Application forms (obtainable from the College) should be sent to the Principal as soon as possible.

THE INSTITUTE OF PHYSICS

Vol. 10 No. 9 BULLETIN SEPTEMBER 1959

Published by The Institute of Physics for circulation to its members

Methodology and Aesthetic Content in Natural Science

By F. I. G. RAWLINS, M.Sc., F.S.A., F.R.S.E., F.Inst.P.

(Scientific Adviser to the National Gallery, and Technical Director of the Central Council for the Care of Churches)

INTRODUCTION

THE progress of physics during and since World War II has provided an example of almost unparalled achievement in large-scale applications—atomic fission, space-rockets and the rest. In this advance, both classical and quantum principles have been involved, though the former have tended to be somewhat overlooked; so much so occasionally that promising research workers in such fields have been hard to obtain. And this in spite of the amount of time and energy devoted to fundamentals at the universities. But it must have become clear to anyone whose task it is to interview young graduates and other people of roughly similar standing, that there is much more at stake than a mere personal preference for this branch of physics or that. What seems to have happened is that the sheer weight and bulk of factual knowledge to be absorbed in—say—three years or so has blunted to a substantial extent the power to see physics as a part (albeit a major part) of *scientia* in the classical sense. In addition, the awareness of a common outlook with other disciplines has become clouded, which is a pity, in as much as frontiers between subjects of study are apt to be very artificial, and drawn where they are more as a matter of convenience than for any epistemological reason. Furthermore, there appears to be little of that joy that used to bubble over at times, not only in moments of discovery, but even in the hammering out of theory, and the presentation of results.

These characteristics may well be bound up with the particular stage which our civilization has reached, and the perturbations through which it is passing, but it may be nevertheless worth while to consider other possible causes underlying the present mental atmosphere.

It would seem, for one thing, that we have lost (or at least have failed to retain in sufficient measure) a sense of the beautiful in abstract knowledge. And again, that this defect is the accompaniment of having given little heed to scientific method (or in general, methodology), at least in so far as it should keep pace with rapid technical advance. For example, the Greeks were very reluctant to conceive of a straight line of infinite length. Euclid was careful to stress when such a line should be " produced " beyond a certain point. So with their architecture, grand as it was, its lines were finite and bounded, restricted to the visual needs, and associated with a sense of touch. Compare this with the aspiration of a Gothic spire, and one gets a glimpse of the liberation which followed upon the idea of a straight line, or axis, stretching to infinity. A wider vista had been gained.

Further, in such a common matter as simple algebraic forms, a notable aesthetic advance was made when (as appears probable) Thomas Harriot of Oxford (1560-1621) first proposed setting all the variables and constants in an equation on one side, and equating to zero, leading to the neat generalized symbol $f(x, y) = 0$. Throughout the ages, the influence of notation has been great, as freeing the mind for things that matter, rather than cluttering it with difficult and cumbersome modes of expression which only add to the labour of bringing thought to full fruition. In recent years, advances in the symbolism of the propositional calculus, and of logistics in general, have resulted in a clarity which would have surprised George Boole when he first published his *Laws of Thought* in the middle of last century. Leibnitz too could not have anticipated the change for the better in semantics when he composed his novel universal calculus, applicable alike to international documents and the study of theology. And in recent years, the possibility of ethics becoming demonstratable in terms of the contemporary three-valued logic, has been seriously discussed.

In 1954 there appeared *The Mind and the Eye*, by Dr. Agnes Arber, F.R.S. This remarkable book is the work of a distinguished plant morphologist, but what the author has to say is applicable to almost any branch of scientific knowledge, and to some of the humanities also. In the sequel, an attempt will be made to scan the horizons of natural science in similar fashion, but any slight virtue this essay may possess will be due, very largely, to Dr. Arber's influence. The fact is that the methodological content and the structure of research are in essence similar for all the " knowledges " (as the late Dr. Tennant would have phrased it). And more than that, morphology is a basic concept, whether for physics or for biology, as indeed it is for that young hybrid bio-physics of which we may expect to hear much in years to come. All in all, the study of *form* is fundamental, whether we meet it in plant life, crystals, or algebraic equations. It is here, we may surmise, that the aesthetic content is to be found, as something which generates not only sensuous pleasure in the ear or eye, but its equivalent in the mind.

THE METHODOLOGY OF RESEARCH

The study of the history of science shows over and over again how much harder it is to ask of nature the right sort of questions than to formulate the answers. And further, the capacity to make this distinction, and to make it without fail, seems to lie at the root of genius for original work. It will seldom, if ever, be found in its pure form related to applied science or to technology: such would almost amount to a contradiction in terms.

Application, as its very name denotes, has for its aim the use—very often on a heroic scale—of a harvest already garnered. The burden and heat of the day is over for the reapers before the benefits (if any) begin to accrue. And it is seldom to them that they do accrue; a situation which is not the fault of society, for the reapers commonly have no thought at all of what use their sheaves may have. They have watered, grown, and gathered, and there they will rest content. Moreover, when the fields are white to harvest, it is then that the scientist (more akin to the artist than is often believed), realizes that something has been accomplished. But if, in this particular he is an artist, and not merely a craftsman, he will stand back from his work and contemplate what manner of thing it is. And if he succeeds in finding satisfaction in it for its own sake, he may hazard the possibility that it is beautiful.

At some such stage as this, there is a parting of the ways, depending upon the personality of the investigator. Whilst he is at full stretch on his problem he is more than ever the analogue of the artist painting his picture, or of the sculptor modelling his statue. But one day the task is done (never of course to satisfaction) and the work of art comes under the eye of the critic (who maybe has never painted a picture in his life), just as the physicist's thesis may attract the attention of the philosopher, who has never been inside a laboratory. And what exactly do these " outside " people do ? They may agree that what is before them is good of its kind. But what of the presuppositions upon which it is built, and the conventions within which it has been constructed ? They will drill deeply into the very foundations underlying the results before them, and ask just how firm they are (and perhaps what degree of permanence they may reasonably be expected to possess). It is not imperative however, for these external examiners to appear upon the scene at all: artist and scientist may well be their own assessors to a large extent. Yet, they will only satisfy themselves if, by a mighty wrench, they contrive to tear themselves away from pigments, media, test-tubes, apparatus and the rest, and allow the mind to relax into a state in which it becomes percipient of abstract content, over and above the means directly employed to produce it.

We are now on the borderland of what has been called the " illative sense." The phrase seems to have originated with Cardinal Newman, who used it to connote a markedly subjective grasp of truth, and not only that, but also a condition in which the whole personality is identified with a forward surge, amounting almost to revelation in a desire to greet veracity. (Philologically, the word is closely akin to inference, for it derives directly from the past participle of the Latin *inferre*). There is a more modern use of the term, in combinatory logic, to define certain quantifiers and categories, which has no connection whatever with the act of discovery. But Newman's insight has its present-day counterpart in the view of Professor M. Polanyi in his recent book *Personal Knowledge* (the Gifford Lectures), in which he denies absolutely the strict objectivity of science. But when all is said and done, the illative sense is most closely related to " taste," that curious emotive sense which finds expression in art as well as in almost every other activity. One peculiarity of it must be mentioned: it looks so easy when the perfect setting, formula, phrase, or mathematical expression is forthcoming. Actually, taste is usually the outcome of prolonged rigour and strife, training and observation. Archimedes knew it well, when he discovered specific gravity and is said to have exclaimed Eureka! Eureka !

Nevertheless, this particular intellectual grace can, to some extent, be taught. Scholarship candidates in mathematics begin to realize instinctively that some solutions to their problems are more elegant than others, and will not rest content with a proof which is adequate though clumsy. It is recorded that Alexander the Great was not a little bored with the tedious demonstrations of the properties of conic sections presented to him by his tutor Menaechmus (the distinguished young man undoubtedly possessed high standards as a pupil, having previously had no less a figure than Aristotle as his director of studies). But here time has brought aesthetic gain in much neater and abbreviated demonstrations for the ellipse, parabola and hyperbola. In fact, the nineteenth century, with its greatly enhanced ideas of proof has added substantially to our sense of the beautiful in all manner of mathematical deductions. This forward movement was itself conditioned to a lesser extent by a pain in the mind regarding what had hitherto passed as " necessary and sufficient." In times long ago, Plotinus and Spinoza wrestled with the problem of absolute truth to such a degree as to obtain a glimpse of it probably without equal before or since. In the sequel, we shall discuss some aspects of relative truth, which is commonly all that we can hope to achieve. Before doing this however, there are certain other matters concerning scientific method to be examined. One is the degree of finality which an investigator sometimes claims for his work. The tendency is often to write something more like a report than a literary communication. It will probably be accompanied by a terse summary, all very admirable from the point of view of clarity, but sometimes disastrous from the aspect of truth-content. So much relevant detail seems to be omitted that the result is more in the nature of a short cut across country than the grand tour. Analogous considerations apply to the uncritical use of Occam's razor, *Entia non sunt multiplicander praeter necessitatem.* This worthy exhortation to parsimony in the use of suppositions, postulates, constants and so forth is all very well, but when used as a convenient method of throwing overboard potentially awkward or unwanted factors, it is to be deprecated. The fault surely is to identify simplicity with validity. Perhaps unfortunately, complexity may be nearer the truth. Or at least this may be so in the present state of knowledge, and we are unjustified in erecting a noble and simple facade containing a mass of incoherent machinery within. It is not merely that the outside is deceptive: the contents are wholly out of keeping with the apparent severity of the design. John Ruskin praised single flowers, and hated double ones, not because the latter lacked grace only, but because they were artificial. Complexity of this sort in scientific writing is obviously far from beautiful. In terms of thought, it is unlucky that there is little opportunity to stress the progress of ratiocination towards truth by means of the Socratic dialogue, or the Hegelian dialectic. These methods—of question and answer in the first case, and thesis and antithesis in the second—are the verbal counterparts of the mathematician's iteration, in which the amplitude of each successive lurch of the variable diminishes as it approaches ever more closely to the true value of the argument.

THE QUEST FOR TRUTH

The experimental sciences have for countless years been conducted upon the belief that the universe is rational. Indeed, on the face of it, a denial of this creed would render much, if not all, of our investigations in science and in technology impossible. Yet the basis for such a view (of uniformity) is singularly insecure, and needing more care than is commonly given to it. Leaving aside the use of analogy (i.e. reasoning from likeness), the uniformity of nature cannot be proved deductively, because there is nothing more general from which such a condition can be inferred. Again, inductive proof is unavailing in practice, since it would involve testing every single process occurring in the universe. But what in normal circumstances seems reasonable is to look upon nature in general as rational, but admitting that there may be a hard case of " brute fact " somewhere, which is intractable. Recent developments of the quantum theory in this regard are too well known to need discussion, but the most recent suggestion of Werner Heisenberg of a " universal matter " akin to the very primitive thought of Anaximander, has an obvious bearing upon the question. Beyond that, it is clear that for classical physics, and for nearly all of technology, the rationality of the universe is unlikely to be challenged. Nevertheless, there are two ways in which the problem may present itself to the philosopher and through him—as it were—to the physicist. The first is to assume that the uniformity of nature is " given " i.e. that like the axioms of Euclid it is assumed to be a self-evident truth. This is a simple methodology—almost verging upon metaphysics, and rendering impossible any further analysis concerning it. The alternative is to look upon the uniformity of nature as a hypothesis, to be tested and retested in every scientific experiment. This method has the advantage that every investigater is in fact contributing something towards strengthening (or perhaps weakening) this all-embracing view. The distinguished German philosopher Vaihinger some years ago, initiated a system of thought to which he gave the name of *als ob* (" as if "), and such a tenet is not far removed from the one well suited to form the bedrock of natural science. We proceed in fact " as if " nature always behaved uniformally, but we are fully prepared that our results should only possess relative validity in that they rest upon the truth of that hypothesis. It is well to recollect that Euclid's formulation (the famous parallel postulate) has always been under fire, and its renunciation has led to the establishment of the non-Euclidean geometries associated with the names of Lobachevski, Bolyai and Riemann.

Philosophers have long recognized three theories of (or perhaps better, ways of regarding) truth. These are (i) Correspondence, (ii) Coherence, (iii) Pragmatic. It will be convenient to dispose of the last-named immediately, before dealing with the other two. Briefly, the pragmatic theory of truth amounts to nothing more than " it works," whatever " it " may be. There is a subtle distinction between this homely result and (i) because no particular coupling between assertion and fact is demanded. In the event, the pragmatist is closely allied (as is widely appreciated), with the " Vienna Circle " of positivistic outlook, which says in effect that anything which cannot be observed and measured is meaningless. Clearly, such a system has no place for metaphysics—however valuable they may have been as stepping-stones in the past—and none for aesthetics, since, apart from Birkhoff's *Aesthetic Measure* (restricted to aesthetic formalism), nobody has succeeded in producing a generalized metric of the beautiful. Meanwhile it is worth noting that the powerful but somewhat ungainly matrix calculus was a method pressed into service to secure for the quantum theory a positivistic principle, namely a relationship between observables (and observables only), in this case frequency and intensity.

The fact that Vaihinger alleged that our reactions to things are mere fictions of the mind does not in itself invalidate the use of his *als ob* philosophy in our discussion of natural phenomena, since should our view of the uniformity of nature turn out to be a mere mental image, it is still all that we can do about it, unless that same mind succeeds in achieving a break-through to some new species of objectivity. The essential point is that hypothesis is much to be preferred to postulate, if only because it keeps the brains of research workers alert for any irregularity, rather than labouring in the enervating condition of accepting a major " given," behind which it is impossible to penetrate. In this context, it is probably unusual for scientists to read the literature of phenomenology, closely associated with the name of Edmund Husserl. But if they study him they will find that he strove for a pre-suppositionless system of thought which led to a process of what is called " reduction " or " bracketting," but which is best rendered in English as " waiving." This means a suspension of judgement which can hover over the question at issue, and can re-engage if and when the advance of knowledge makes such a course feasible or desirable. It was originally introduced by Husserl as a serious alternative to Descartes' "universal doubt," with the well-known and inveterate dualism which necessarily accompanied it.

The Correspondence theory of truth (i) is, in essence, not so much a theory but a doctrine, namely that of "telling the truth" in the usual sense of the term. Scientists do well if they frame their statements as nearly as possible to "correspond" with the facts. An alternative name "congruence" has been suggested. This brings to mind the accurate overlay of the geometer, with its implication of a good fit both in size and shape. It is probably the (largely subconscious) kind of truth accepted by the technologist, who is working with large-scale examples or exercises in physics rather than with original conceptions. It is well also to be on guard to separate out what are called contingent truths when they occur. An example would be the observation that a section of granite under the microscope showed pleochroic haloes. It is conceivable that granites would be found which do not exhibit this phenomenon of radioactivity, and indeed such non-pleochroic granites are common enough. This is a species of truth of which the opposite is by no means inconceivable. It differs entirely from some of the basic assertions of mathematics, which exert a wholly coercive effect upon the human mind. Nevertheless, the experimentalist can usually give limits of error for his results, and even provide a fair measure for the degree of reproducibility attainable. It is in matters of this sort that technique plays a major part in reducing both the "scatter" of observations and the capriciousness of their repetition. An instance of this is the enormous improvement in recent years in the accuracy of plotting and recording intensities in infra-red spectra. Forty years ago, deviations of around ten per cent were not uncommon. To-day, with automatic charting, uncertainties have been reduced to almost trivial proportions.

The Correspondence theory of truth has its defects, which its simplicity and convenience tend to obliterate. One is that it stresses the objective aspect unduly. Another is that no tenet of a scientific nature is permanent : as Heraclitus observed, all things are in a state of flux. Correspondence or congruence would pin down truth rather too rigidly. Reverting to the objective issue, two further points may be made. One is that a truth needs to be assimilated thoroughly by the mind of the enquirer (and of the artist too) before it can become "veritable" for him. Again, in the last resort—and this is probably the last resort in this particular context—Heisenberg's uncertainty principle precludes, in the limit, a one-to-one relationship between the position and momentum of an electron at a given moment with respect to a given observer. In which case, an object "seen" is never uninfluenced by being observed, in whatever manner that observation is made. That this extreme state of affairs represents something of no immediate practical importance is neither here nor there. What is essential is to realize that, purely epistemologically, the Correspondence theory of truth is a good working guide, but that its characteristic objectivity is not an ultimate virtue. It is rather an argument once more for allowing a place for the subjective element stressed in Polanyi's *Personal Knowledge.*

The Coherence theory of truth (ii) is a different matter. It is more complicated than correspondence or congruence; its main feature (as its name implies) is that every implication or ramification of something primarily alleged to be true should cohere, or hang together. It is unlikely therefore that a scientist's "raw" results will in themselves satisfy the criteria to qualify for a coherence test for truth. This conception means that the original claim to be true is continuously subject to confirmation or rejection in the higher court of coherence. In brief, coherence is more refined than correspondence or congruence, and its judgement takes account of any lower submission at the bar of mere "copy." An example might be the second law of thermodynamics: this as usually enunciated was, until recently, believed to be incontrovertible. But modern quantum mechanics is not disposed to accept without reservation as inevitable the "heat-death" of Ludwig Boltzmann. The universe, as a whole, is not running down, though this means bringing within the concept of entropy systems other than those originally envisaged. So, the second law, as commonly accepted, may be acclaimed true to the degree required by correspondence or congruence, but not to the level needed for coherence, because further reticulation of the theorem (as indicated above) reveals implications at variance (even though not perhaps verifiable directly) with the original postulate as a "copy" of the facts in question.

AESTHETIC CONTENT

A simile between scientist and artist has already been suggested. It is now intended to follow up this imagery a stage further with a view, amongst other things, of seeing to what a point of vantage we are conducted, if we use the discriminants of truth already outlined as our guide. English, in many ways a satisfactory tongue for the scientist, is not as rich in shades of meaning as the European languages in some instances. Particularly is this so with regard to the word "truth." In German, we have *Richtigkeit* or correctness, and *Wahrheit*, the Hegelian thought-content in harmony with its own essence. We are near the frontier of metaphysics here, in an attempt to codify our experience, but one distinction comes out clearly, namely that *Richtigkeit* goes naturally with correspondence or congruence, and *Wahrheit* with coherence. Again, the former is, in general, the domain of science, the latter that of philosophy. Indeed it would be tempting to use the time-honoured term "natural philosophy" for the region wherein *Richtigheit* is being sublimated into *Waheheit* (as indeed Dr. Arber suggests doing in her book already mentioned), were it not that north of the border natural philosophy means simply physics. But perhaps not quite. In the Scottish universities, there is a definite slant towards that older tradition (probably Continental in origin), which brought mere "correctness" more closely into contact with speculation, stimulated, perhaps by the subtle distinctions needed to combat the excessive Aristotelianism of the schoolmen.

The distinction already mentioned between the two degrees of truth lies at the root of the aesthetic content in works of science no less than in works of art. One of the most complicated tasks of the art-historian is to follow the tangled skein of truth not only through " schools " of painting and (say) architecture, but even through the vagaries brought about by the divergent stresses characteristic of artists even within the same " school." For each one of them " truth " was something slightly different: they were not in the least ashamed of this, and the totality of their efforts may be compared to the different facets and their inclinations in a crystal. They repudiated a photographic likeness in our sense. And it is hard to see why scientists should be bound too slavishly to a hard-and-fast pattern. Such latitude, naturally, is confined to study in morphology (whether organic or inorganic): it is scarcely applicable to abstraction. A famous Russian physicist is reported to have remarked—many years ago—" I delight in bias." No doubt there is much value in this attitude, for it is only by the disciplined exercise of the imaginative faculty that momentous advances are made. This takes us back to the " illative sense " already mentioned. Its strength is artistic, but its force is intellectual. Bring the cold light of reason upon its findings, and it will stand up to the strain. Gödel's theorem of the impossibility of proof in certain consistency propositions is a case in point.

It should perhaps have become clear that a very complex connection exists between sense data and their assessment by the mind. When the discovery was made that we see because light is reflected from an object in the field of view into the eye (and so on to the retina, and thence to the brain), much more than a formal advance had been achieved. The whole epistemological basis of natural science becomes clear, because the eye thus functions as the window of the mind, which sees through it rather than with it. The ancients sensed this metaphysically, making the eye ancillary (i.e. as a serving-maid) to the mind, in much the same way in which philosophy was regarded in the middle ages as ancillary to theology. Whatever views may ultimately prevail as to the nature (if any) of visual *gestalten*, one thing is clear beyond dispute, and that is that the mind has the capacity to integrate quite discordant and substantially imperfect visual images into a meaningful whole, which it can interpret and enjoy. In this it roughly resembles the kaleidoscope, which can fuse all manner of bits and pieces into something beautiful. But whether the mental process is directed towards the unification of sensations, or absorbed in the reception of sensuous pleasure in beholding colour or form, it will only be significant if it allows of contemplation of the effect *for its own sake*, wholly without reference to use or value.

CONCLUSION

The neutral position towards axiological standards which we have now reached lies at the very root of pure science. It is also seen to be fundamental for the attainment of aesthetic experience. To say that this means some sort of identity between science and art would be to fall into the bottomless pit of false analogy. But it points to a common habit of mind, odd as that may seem, in the sense that observation, measurement, inference, all fail to satisfy if they do not add up to produce something which is more than " good of its kind." It is at the moment of standing back from a task accomplished (whether on the bench or on the easel) that human thought makes its greatest effort to discern whether only a " copy " has emerged, or whether access has been gained to that arena of achievement wherein every legitimate claim of implication has been met by reticulation or coherence. Part of this sublimation is embraced within Goethe's *Weltanschauung*, or intuitive knowledge. The remainder, apparently, comes from nowhere but a monolithic discipline of the emotions, bringing them into close harmony with man's mental powers.

It was written by one of old that wisdom peeps in at the window. If and when she does, the mind is illuminated in its quest for truth.

The Qualities of a Good Science Teacher*

By CYRIL BIBBY, M.A., M.Sc., Ph.D.

(*College of S. Mark and S. John, University of London Institute of Education*)

When I was invited to give this paper I was initially somewhat hesitant. This was not because of the subject, which is one in which I am intensely interested, but because of the sponsoring organization. There are, after all, many excellent physics teachers who might have spoken instead of me, and perhaps they would have been more at home in this Institute. However, in extenuation of my being a biologist rather than a physicist, I may plead that I did as a student have the privilege of working in the Cavendish, and that I taught physics and chemistry for some years before moving definitely across into the biological sciences. So perhaps, in some ways, my lamentable apostasy from the physical sciences may help me to take a wider view of science teaching than a more *pukka* physicist might do.

There is one other explanation which I should make before getting down to brass tacks. Education, unlike physics, has no necessary correlation between recency and relevance, and you must not therefore be surprised if some of the points I make seem not at all novel. A student of physics to-day, I suppose, could gain little but antiquarian interest from reading the writings of Archimedes, or even of a comparatively recent physicist like Tyndall, but that is not true of education. Many of the most illuminating suggestions on education generally, and on science teaching in particular, are somewhat antique—but none the less valuable for that. And, if one thinks of the great scientific educators—people like the Edgeworths and T. H. Huxley and A. N. Whitehead—most of what they had to say is as relevant to science teaching to-day as it was when they first wrote.

With this by way of preliminary, I come to my theme: what are the qualities of a good science teacher ? And, as is so often the case in considering a complex question, it is useful to start with a very simple answer as a first approximation : the good science teacher must be a good scientist and a good teacher.

Simple as it is, and obvious as it is, even this statement is by no means always accepted as true. There are many people, and some of them in high places in educational administration, who are quite content to close their eyes to one or the other of these two desiderata. For years some of the two-year teachers' colleges have been sending out into the schools great numbers of men and women who have only scratched the surface of science considered as mere knowledge and who have barely begun to experience science as an actual process of investigation. For years the universities have been sending into the schools men and women who have graduated in science but who have never received any sort of professional training for what is to be their life's work. This is not to say, of course, that there are not some good scientists among those who have learned what teaching is, and some good teachers among those who have learned what science is, but we are still a long way from universal acceptance of my simple dual requirement.

It is as true now as it was when T. H. Huxley made the point in his *Science and Art in Relation to Education*, that :

> " There are a great many people who imagine that elementary teaching might properly be carried out by teachers provided with only elementary knowledge. Let me assure you that this is the profoundest mistake in the world . . . there is nobody so hard to teach properly and well as people who know nothing about a subject . . . to be a good elementary teacher, to teach the elements of any subject, requires most careful consideration, if you are a master of the subject ; and, if you are not a master of it, it is needful you should familiarize yourself with so much as you are called upon to teach—soak yourself in it, so to speak—until you know it as part of your daily life and daily knowledge, and then you will be able to teach anybody."

Let me now look through the other end of the telescope, from the point of view of the pupil rather than of the teacher. If we can first decide what things the pupil should gain from his science lessons, we may then be able to deduce what qualities his teacher needs to give him these things. And we must bear in mind that at this conference we are concerned not with the small minority of pupils who will be the practicing scientists of the next generation, but with the whole age-group who will be bus drivers, housewives, insurance clerks, navvies, shop assistants and what-will-you. These pupils, after the age of eleven, may be in different sorts of secondary school, and the conditions of the particular school are bound to influence decisions on the content and methods of the science teaching, but this does not affect the main issue. With each year that goes by, more and more evidence accumulates that the whole theoretical basis of our tripartite secondary selection is invalid, and even those administrators who love simple classifications are being forced to admit that it is not quite so easy to specify the points of a human being as of a shorthorn cow or a Siamese cat. In what follows, therefore, I shall largely ignore the distinctions between different types of secondary school.

What, then, could secondary school children gain from good science teaching ? In the first place, obviously, some knowledge of the facts of science. But, as the then Head of Winchester correctly remarked to the Clarendon Commission in 1864, a scientific fact is " simply a barren fact, which he remembers or does not remember for a time, and which after a few years becomes confused with other facts and is forgotten." What Moberley failed to see is that the same is true of a grammatical fact or a linguistic fact or indeed a fact of any kind : in itself it may be forgotten and fail to bear fruit. (How many of the school-learned facts which they knew at fifteen do the average man and woman still remember at twenty-five ?) Unfortunately, there are many teachers still living in the world of Dickens's *Hard Times*, where, you will remember, Mr. Gradgrind impressed on Mr. M'Choakumchild, " Now, what I want is, Facts. Teach these boys and girls nothing but facts. Facts alone are wanted in life. Plant nothing else and root out everything else." It is only when the facts are taught in a certain way that they germinate, that they grow into a vital part of the developing mind. Of recent years, the *Gestalt* psychologists have emphasized the importance of perceiving whole relationships, but I prefer the vivid presentation of Newman in his 1852 discourse on " Knowledge viewed in relation to learning " :

---

*An address given to the Conference of the Education Group at the Institute's House on April 2, 1959.

> " There is no enlargement, unless there be a comparison of ideas one with another, as they come before the mind, and a systematizing of them. We feel our minds to be growing and expanding *then*, when we not only learn, but refer what we learn to what we know already. It is not the mere addition to our knowledge that is the illumination, but the locomotion, the movement onwards, of that mental centre, to which both what we know and what we are learning, the accumulating mass of our acquirements, gravitates."

This, then, is one quality of the good science teacher: *that he teaches facts in such a way as to germinate in his pupils' minds, in such manner as to help their minds to grow and expand and make comparison of ideas one with another.* And the failure to do this is in itself a condemnation of much of the general gadgetry which so often passes itself off as " general science."

But there is more to it than this, for the facts of science are so numerous that only a tiny proportion of them can be taught in schools, and there must be criteria of selection. All too often, I fear, the criterion is simply the contents-page of a chosen textbook—and, more often than not, the authors of textbooks have merely copied the contents of textbooks already in print, and usually based on some traditional examination syllabus. It is a salutary exercise for a science teacher to trace the contents of textbooks and examination syllabuses back for three-quarters of a century, and see how little fundamental change there has been. New chapters and new sections have been laid on top as the passing decades brought new scientific discoveries, so that some of the earlier material has been compressed and dehydrated in the manner of early carboniferous fossils under accumulating sedimentary deposits, but there is remarkably little trace of any new pedagogic thinking. As a result, any average elementary chemistry text is still largely preoccupied with the alkalis and acids, the ferrous metallurgy and the qualitative analysis which reflected the industrial chemistry of England in the nineteenth century. What started as a vitally topical syllabus, relevant to contemporary scientific industry, has now become so remote from utility that its retention is currently justified on the same grounds of " mental training " as are used to defend other traditional useless studies. Or look at biology books, and see what a large part is still played by the "type species" which happened to be used in T. H. Huxley's 1870 summer vacation course for teachers at South Kensington—or, alternatively, by the lady-like floral dissections which were considered suited for the virgins, young and old, who studied and taught in the first establishments of higher education for females. As for the physics texts, I must refrain out of courtesy to my hosts from particularization, but even as a guest I may be permitted to suggest that the school-books of your specialism would warrant similar scrutiny.

Here, therefore, is another quality of the good science teacher : *that he gives the most careful thought to the selection of the facts which he will teach and, instead of following in traditional ruts, establishes valid criteria of selection.*

Among these criteria, I suggest, should be the following :

- the immediate utility of the facts in the daily life of childhood
- the probable future utility of the facts in the daily life of the next five decades during which the pupils will be adult
- the relevance of the facts to twentieth-century scientific industry
- the interest of the facts for the pupils
- the interest of the facts for the teacher
- the value of the facts in building a coherent and logical basis for a systematic understanding of science
- the place of the facts in illuminating those great scientific themes which must be at the centre of any valid modern philosophy.

Having selected the facts which he will teach, and ordered them into a pedagogically sound curriculum, the teacher must then consider how thoroughly he expects his pupils to learn them. Too often, in adopting the unrealistic idea that his pupils should learn perfectly all that he teaches, the science teacher ends up with a class which knows nothing properly—and this applies at all levels, up to and including the university, wherever the examination system expects examinees to load their memories with masses of detail whose retention is far better left to scientific encyclopaedias. What is necessary is a meticulous examination of the facts in the science curriculum, and their separation into two great classes: the minority of facts, which are so central to the logical development of theory, or so frequently needed in application, that they must be learned by heart and so be capable of exact reproduction at any moment ; and the majority of facts, which help to illuminate theory, or are of intrinsic interest, but not a necessary part of the minimum corpus of knowledge, and therefore need to be thoroughly understood and capable of intelligent recognition when they crop up again but not to be learned by heart. Such a division of the total body of facts not only gives the pupil a manageable load of rote learning and leaves his memory uncluttered with unnecessary lumber, but also gives the teacher an invaluable guide to those parts of his syllabus which must be emphasized and those which can be dealt with more lightly, thus enabling him to introduce into his teaching those variations of pace which produce liveliness and avoid boredom.

It is, then, a quality of the good science teacher *that he not only selects carefully the facts he will teach but also* *distinguishes the degrees to which he will labour different facts, and decides which facts he will expect his pupils to learn as " reproduction knowledge " and which they may be content to understand as " recognition knowledge."*

So far, I have spoken of the teaching and learning of facts, but have said little about the modes of teaching and learning. Now we must consider other qualities, related to the special potentialities of science as an instrument of culture.

This last phrase has been used deliberately, to emphasize a pedagogic truth of prime importance : namely, that the job of the science teacher is not simply to teach science, but to educate through the medium of science. It is the whole child who is being educated, and the science teacher can do much more than teach science as a field of knowledge. He can provide useful knowledge, but he can also be helping to form a philosophical attitude, and providing exercise in exact observation and exact communication, and developing discrimination of the senses and aesthetic appreciation, and leading his pupils in an adventure of inquiry and fostering their creative impulses, and encouraging them to be sceptical of all authority except the inalienable authority of nature itself.

It is one of the prime marks of the good science teacher *that he is vividly aware of the immense potentialities of his task and determined not merely to teach his pupils science but to use science as a medium for the education of the whole personality.* Space does not permit the detailed examination of the whole of this great task, but some elements are so important as imperatively to demand further scrutiny.

First, there is the matter of exact observation and exact communication. These two I link together, for science is a social activity in which the latter is as important as the former and the two interdependent. Not that one would think so, to judge from many of the communications in the scientific journals. It always astonishes me, to read papers by scientists, whom I know from personal acquaintance to be clear-minded and capable of coherent and clear conversation, but who apparently feel it necessary when describing their discoveries to clothe them in obscure and complex gobbledygook. I am not referring to the necessary use of technical terminology, but to an apparently compulsive use of the third person passive, an almost universal phobia of illuminating imagery, an endemic tendency to verbal flatulence. I can only suppose that those who have the patronage of research posts equate literary skill with scientific unreliability and confuse objectivity with flatness. And, sad to say, just as science masters tend to take as their curricula a diluted version of university curricula, they tend also to take the phoney unhumanity of research papers as a model for their pupils' laboratory notebooks, so that a child's vivid phrase " I next heated it in a flame" is 'corrected' to "The test-tube was then held above a bunsen burner," or even " The mother suckled her baby " ' corrected ' to " The neonate was approximated to the mammary glands of the maternal parent." I recommend all scientists and science teachers to a course of reading in the research papers of T. H. Huxley, where they will see how objectivity of description can be combined with crystalline clarity of expression in a perfection of scientific communication.

By exact observation I do not necessarily imply quantitative measurement—although that may be one form of it. I commonly note among my physicist friends a somewhat superior attitude in this respect, with an implicit (and sometimes an explicitly stated) assumption that the qualitative observation so important in biology is in some way less " scientific " than the numerical measurements more common in physics. It is true, of course, that in general the biological sciences have not yet been so largely quantified as the physical, but that does not mean that in them exact observation is less important or less common. And, so far as their educational values are concerned, I am inclined to think that the balance of advantage lies with exact qualitative observation. Consider, for example, the mental enlargement which must have come to the young children who were so fortunate, two centuries ago, as to be taught simple science by the Edgeworth family. Here is a description, from their 1798 *Essays in Practical Education*, of the way in which a child can observe and investigate an everyday optical phenomenon :

> " A boy of nine finds a kind of rainbow on the floor. He calls his sister to see, and wonders how it came there. The sun shines brightly through the window. The boy moves several things upon which light falls, saying ' This is not it. Nor this ! ' At last, when he moves a tumbler of water, the rainbow vanishes. There are some violets in the tumbler, which he thinks may explain the colours on the floor. But when the violets are removed the colours remain. Then he thinks it may be the water. He empties the glass. The colours remain but they are fainter. This leads him to suppose that the water and the glass together made the rainbow. ' But,' he adds, ' there is no glass in the sky, yet there is a rainbow, so I think the water alone would do so, if we could but hold it together without the glass.' He then pours the water slowly out of the tumbler into a basin, which he places in the sunlight, and sees the colours on the floor twinkling behind the water as it falls."

And that single passage, incidentally, seems to me to provide the complete answer to those who question whether science can be taught in the primary school. Of course it can, if there are teachers who know what they are about.

A child who has learned to observe accurately and describe succinctly what happens when two chemical substances are heated together, or when a frog eats a worm, or when a soft rubber ball is bounced, has had an experience much more valuable than that of weighing a crucible to the nearest milligram or determining the precise pH of a soil with a hydrogen electrode or measuring the internal diameter of a brass tube with a travelling vernier microscope. I am not saying that these latter activities should not have a place in school science, just as they may be essential in a particular scientific investigation, but I do claim that the quantitatively exact measurement of an essentially simple parameter does not present the same challenge or provide the same opportunity of mental enrichment as the qualitatively exact description of a complex process. People sometimes speak of science as " developing the faculty of observation," as if observation were in fact a simple faculty, but matters are more complex than that. Some sorts of observation depend especially on fineness of visual discrimination, others on delicacy of handling measuring instruments, others on the sensitive detection of sounds or textures or odours, others on the immediate intuitive analysis of movement, others on the over-all apprehension of a total situation, others on the isolation of the relevant from the irrelevant.

It is a characteristic of the good science teacher *that he recognizes the immense potentiality of exact observation in developing a wide range of personality attributes and so plans his pupils' practical work as to provide opportunities for such wide development.*

I said earlier that exact observation was closely connected with exact communication, and this theme warrants further consideration. It might be argued that it is perfectly possible for a scientist to observe something without uttering a word about it to anybody, still less writing about it, and this is true. But it is true only because the scientist is himself the heir to a long social process of communication between scientists through the centuries, a process which has provided him with the words and the units of measurement and the very concepts which he uses in his observation. In the process of observing, he is in effect carrying on a soliloquy during the course of which there is a complex internal autocommunication of sense-data and unspoken verbalizations and habitual conceptualizations : he is doing everything except actually speaking or putting pen to paper. Sometimes one is aware of this sort of process in pupils, who have evidently observed quite well but have not yet taken the step of external communication, and perhaps find that final step difficult. And in their case—for these are children still under formal education, not working scientists already passed through that stage—one notices something else : the taking of the final step, with appropriate help from the teacher, produces a sort of back-reaction which actually helps to clarify and complete the preceding process of observation. In fact, the person who goes no further than observation rarely gets as far as observation : in order to get that far, it is necessary to go farther, as far as communication. Whether this communication takes the form of carefully written notes, or of formal verbal description to the teacher, or of informal conversation between class-mates, or of communication-by-surrogate in mentally agreeing with a description given by another observer, or even (as in the sophisticated case of the experienced investigator referred to earlier) of unspoken internal autocommunication, is not essential : what is essential is that, in one way or another, the processes of exact observation and exact communication are interconnected. And it is by providing repeated practice in this interconnection that science lessons can most valuably foster in children that clarity and coherence of apprehension and expression which is the great distinction of the educated person.

The good science teacher, therefore, has this quality: *that he attaches great importance to the exact communication of observations exactly made and regards no scientific experience of his pupils as complete until it has been in some way given expression.* I do not want to belittle the aid which the science teacher can give to his colleagues in charge of language by way of correcting spelling and grammar and syntax, but above all he can help by developing the child's ability to use language effectively for its prime purpose, the social communication of experiences and ideas.

I referred earlier to the rôle of science teaching in developing discrimination of the senses, and I suspect that therein lies the key to much future educational advance. Our traditional Western culture has produced a magnificent intellectual and artistic edifice with a correspondingly magnificent technology ; but it has also produced millions of people apparently incapable of enjoying the longer lives which are now theirs, and apparently without aesthetic sensitivity or sensuous richness. Our educational system has paid great attention to simple skills and to complex ratiocination, but comparatively little to the education of the senses. Our teachers devote themselves conscientiously to the often heart-breaking task of taking their pupils through the mental gymnastics which constitute so much of schooling, but in general they disregard the more basic work of ensuring that their pupils' sense-experiences provide a sufficient and a sufficiently correct knowledge of the world to which the results of the mental gymnastics are meant to be relevant. Our education has been too verbal, too abstractly conceptual without adequate sensual foundation, and I doubt if we shall get much further along this tack. We can, no doubt, achieve some improvement, and certainly we can raise the deplorably low level of literacy with which some of our schools have been content, but for any great new development of human personality I suspect that we shall have to get down to fundamentals, to the education of that total psychosoma of which the intellect is but one aspect.

If ever we succeed in doing this it will be a pedagogic revolution of the first order, and in that revolution the natural allies are the scientists and the creative artists. These are the two groups who work with their hands as well as with their minds, who progress by becoming sensuously aware of the properties of natural materials and then utilizing that awareness in the purposive manipulation of them, who are always looking for significant patterns in the complex totality of things, whose work involves and expresses not only intellectuality but the whole person. Perhaps that is why scientists and artists seem so often to be happy in their work, sometimes so deeply engaged that the rest of the world tends to regard them as rather cranky. Educators have scarcely begun to investigate the cultural potentialities of systematized sense-exercising, and it will be a long and difficult job. But, in the meanwhile, we can recognize that science teaching, like art teaching, provides a natural arena for exercises of this sort, and encourage rather than frown on them. Young children take a natural joy in all their senses, but they soon learn that certain sense-experiences must not be spoken about and are best avoided or at least hidden. Consider, for example, how much of this native joy in the senses miraculously survives eleven years of repression, right into the first year of secondary school science. And consider, sadly, with what righteous determination some science teachers quickly complete the extirpation of these surviving remnants of innocent awareness ! Penetrating comments about penetrating odours are suppressed as mere rudeness ; fascinated observation of the precise manner in which the hydrogen bubbles form on granulated zinc is interrupted for the more serious business of learning by heart that $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$; aesthetic appreciation of the beautiful scales revealed by a microscope on a butterfly's wings is brushed aside with the brusque comment " Don't sit staring : this is a science lesson "—and, all too soon, the pupils learn the falsehood that science is mere intellectualization instead of being the adventure of inquiry by the whole personality which in their childhood innocence they had (quite correctly) assumed it to be.

It is a mark of the good science teacher *that he recognizes science to be an activity of the whole creative human personality and so teaches it as to encourage not only logical understanding but also sensual discrimination and aesthetic appreciation.*

This exploration of the world requires, for success, a determination that in the last resort the world itself shall be the final authority ; and a necessary implication of this is an attitude of scepticism towards all authority. It implies that the teacher sets up neither himself nor his textbooks as infallible, that there is never an experiment which " doesn't work " but only experiments which produce unexpected results, that the work of pupils is to be judged not by the approximation of their results to the " right " result but by their care and honesty in observation and communication. It means also that the teacher must never fudge, never pretend, never hesitate to say " I don't know " or " Well, we haven't really proved anything." Sometimes, observing the preoccupation of science teachers with " correct results " rather than honest thoughts, one is reminded of Samuel Butler's *Erewhon*, where the Professor of Worldly Wisdom in the College of Unreason remarked " It is not our business . . . to help students to think for themselves. Surely this is the very last thing which one who wishes them well should encourage them to do. Our duty is to ensure that they think as we do, or at any rate, as we hold it expedient to say we do."

I do not, of course, suggest that children can discover the whole of science for themselves. This is the fallacy of the uncritical advocates of the " heuristic " system especially associated with the name of H. E. Armstrong. Taken to extremes, it implies that every third-former can discover in a double period what took Priestley several years, forgetting that science is a cumulative social phenomenon in which each generation starts where the previous generation left off. Even a pigmy, standing on the shoulder of a giant, can see farther than the giant can, and this is how learning advances. It is necessary not only for the schoolchild, but also for the research scientist, to take much on the authority of other scientists : but the point is that the authority should always be accepted only provisionally. Thus, while the teacher will expect his pupils to accept many statements on the authority of print, and more on his own authority, he should continually emphasize that these are always subject to the higher authority of observed fact. He should, moreover, repeatedly draw attention to the differing degrees of certainty with which he makes, or the textbooks may properly make, different statements, and thus gradually accustom his pupils to the exercise of varying degrees of acceptance and varying degrees of scepticism. This is not only a necessary element in the scientific attitude, but an invaluable prophylactic against the authoritarian and conformist tendencies of the modern world. It is important that our children should grow up with some understanding of natural science : it is much more important that they should grow up with a strong tendency to query the statements and attitudes with which they are inundated by all the media of mass communication.

Thus, an important quality of the good science teacher is *that he repeatedly impresses on his pupils the primacy of observed facts and habitually accustoms them to examine critically all statements made on any authority other than that of direct observation.*

This quality of only provisional acceptance of all authority except that of observed facts is intimately connected with a high regard for veracity. In Victorian times there was much debate about what was the truth, but no question that the truth must be sought. *Magna est veritas et prevalebit* was the highest belief of our ancestors a century ago, and I wish we could say the same of our own generation. It is very easy, as some of our leading churchmen and philosophers and politicians do, to point out that the nature of truth is perhaps more complex than an earlier generation appreciated ; but it is sad to see how many of our popular pundits not only emphasize the complexity of truth but even seem to minimize its importance. We recently had in *The Observer* the spectacle of the Primate of All England, in answer to a series of questions by a journalist, so dealing with what he called " moral truth " (which he quite failed to define and which in his usage seemed perilously close to " that which has a good intention ") as almost to imply that the factual truth of one's beliefs is comparatively unimportant. That, of course, has been the justification of the " moral truth " of Hitlerism and of Stalinism, and of conformist authoritarianism in all ages. Against this view the scientist and educator must proclaim that the heart of morality is veracity, and that no so-called " moral truth " can be moral except it be based on veracity. This is not to say that one may not have all sorts of legend and myth and hope and aspiration, nor that knowledge of facts necessarily produces goodness ; but only that the word " truth " is a high word, not to be whittled away on grounds of expediency.

Most of all, therefore, it is a mark of the good science teacher *that he has a passion for truth, an impatience with equivocation, a contempt for all double-speaking, and that by his whole attitude and example he instills in his pupils a veneration for veracity.*

This, of course, should also be a quality in all teachers of any subject whatsoever, and the same applies in differing degrees to each of my other prescriptions. The subject-matter of the natural sciences, and to a certain extent the methods, are different from those of other school subjects ; but, if science is to be truly educative and not merely technologically useful, it must, like all other school subjects, express and foster the whole human personality. We are back, therefore, where we started. Our first approximate answer has been developed in some detail, but it requires no amendment : the good science teacher is simply a good scientist and a good teacher.

Notes and News

Proposed amalgamation of The Institute of Physics and The Physical Society

The scheme for the amalgamation of The Institute of Physics and The Physical Society recommended by the Board of the Institute and the Council of The Physical Society was circulated to Fellows and Associates on August 7 last, together with a covering note from the two Presidents and an explanatory memorandum. If by some mischance, any Fellow or Associate has not received a copy of this important document, and wishes to have one, he should request his copy from the Secretary of the Institute.

Physics as a Career

The second edition of *Physics as a Career* will be published by Chapman and Hall Ltd., on behalf of the Institute, on September 30. The retail price is 8s. 6d. : members of any grade may obtain one copy for their personal use at the reduced rate of 6s. 6d., including postage. An order form for members will be found on page ii.

Salary Survey

A fourth survey of salaries and other emoluments received by Fellows, Associates and Graduates of the Institute will shortly be made. An enquiry card will be sent to each member of these three grades residing in Great Britain in the course of the next few weeks and it is hoped that the response will be at least as high as in the previous surveys, since the value attaching to the report depends upon the degree to which the survey is representative.

International Conference on Physics Education

The International Union of Pure and Applied Physics is sponsoring an International Conference on Physics Education which is to be held in Paris towards the end of July, 1960. Attendance at the Conference will be restricted and by invitation ; it is not expected that more than six representatives will attend from any one country. The Chairman of the Organizing Committee is Professor Sanborn Brown of the Massachusetts Institute of Technology and the Secretary is Mr. Clarke, the Deputy Secretary of the Institute. The various sessions will cover all aspects of physics education from the introduction of the subject in schools to problems of postgraduate training and of technological education.

Bulletin: Display in libraries of schools, colleges and universities

Members who teach in universities, recognized technical colleges and schools are reminded that they may obtain extra copies of the *Bulletin*, free of charge, for display in the libraries of these institutions. Requests should be addressed to the Deputy Secretary. An additional copy for this purpose will be sent each month; copies are available only through members.

Contributions to the Bulletin

Although there is a large amount of material in hand for publication in the *Bulletin*, the average delay in publication of articles being several months, the Editor is always glad to consider contributions from members in the form of either short articles or correspondence. Articles of less than 2,000 words are always particularly welcome. They may be on any topic likely to be of interest to members and not so predominantly technical in nature that they would be more suitable for publication in one of the Institute's scientific journals. **All articles submitted are subject to refereeing. Manuscripts should be addressed to the Deputy Secretary.**

National Certificate courses for technicians working in instrumentation and automatic control

The Joint Committee for National Certificates in Applied Physics has been considering the educational needs of technicians in the field of instrumentation and automatic control. To meet these needs it is prepared to consider a modified form of Ordinary and Higher National Certificate course along the following lines :—

Ordinary National Certificate. The first year might consist of mathematics ; physics ; engineering drawing; instrument workshop practice. The engineering drawing should approximate both in time and in the standard achieved to that of the first year of the Ordinary National Certificate in Mechanical or Electrical Engineering. The second year might consist, as now, of mathematics, physics and chemistry, with the additional subject of instrument technology and practice ; in the third year the subjects could be mathematics, physics and applied physics, with instrument technology as an addition. Students succeeding in this course would receive an Ordinary National Certificate in Applied Physics endorsed in the subject of Instrument Technology.

Higher National Certificate. The first year of this course could consist of mathematics, physics and instrument technology, the last subject dealing particularly with the properties of materials and the applied mechanics appropriate to the subject. In the final year mathematics and physics would be taken with instrument technology (or automatic control), with some emphasis upon whatever aspects of these subjects might be appropriate in the light of local needs. Successful students would then receive a Higher National Certificate in Applied Physics (Instrumentation). The Committee hopes that as precision engineering is an important part of instrument technology, the engineering aspects of the subject would be borne in mind throughout the course. It will be appreciated that this suggested course-structure is intended only to indicate the general arrangements which would meet with the Joint Committee's approval ; the Committee will be willing to consider sympathetically alternative schemes. Colleges wishing to make transitional arrangements to enable students who have already embarked on a normal scheme to transfer to one with an instrument bias are at liberty to submit suggestions for such transitional arrangements to the Joint Committee.

The Institute is prepared to grant to students successfully completing this Higher National Certificate course the same measure of exemption from the Graduateship examination that is available to students now taking the normal Higher National Certificate course.

Physical Society Conference

A conference on Electron-Phonon Interaction in Solids will be held at Oxford on December 17 and 18, 1959. The main sessions will be as follows—Transport properties of metals (general theory); Influence of plasma effects on transport properties; Contribution of phonons to transport phenomena. The main speakers will be: Dr. S. Raimes (*Imperial College of Science and Technology*), Dr. G. V. Chester (*University of Birmingham*), Dr. D. K. C. MacDonald (*National Research Council, Canada*), and Dr. F. J. Blatt (*Michigan State College*).

Anyone who would like to contribute a paper is asked to get in touch with Dr. D. ter Haar, Clarendon Laboratory, Parks Road, Oxford, stating the subject and the approximate length (time). This information should be sent to Dr. ter Haar by October 10, 1959.

Physical Society: Charles Parsons Memorial Lecture

The Charles Parsons Memorial Lecture of The Physical Society will be given by Dr. C. R. Burch on "Aspheric Reflecting Microscopes" at the Science Museum, London, on October 22, at 5 p.m.

Illuminating Engineering Society: Golden Jubilee Lectures

The Illuminating Engineering Society has arranged four lectures to be given in October. On the 15th Sir Lawrence Bragg lectures on " The Nature of Light," at the Royal Institution; on the 20th Mr. L. J. Davies on " The Generation of Light," at the Institution of Electrical Engineers; on the 22nd Dr. W. H. Glanville on " Light and Road Safety," at the Institution of Civil Engineers; and on the 27th Mr. A. N. Irens on " Light and Productivity " at the Federation of British Industries.

The lectures begin at 6 p.m. Admission is by ticket and members who wish to attend should write for tickets (stating the lecture or lectures concerned) to the Secretary, The Illuminating Engineering Society, 32 Victoria Street, London, S.W.1.

Without Comment

Seven Days' C.B. for Army Apprentice

Ronald Daykin, aged 18, an Army apprentice who handed in a blank paper at an examination, was sentenced to seven days' confinement to barracks by the commandant at Arborfield Apprentices' School, Berkshire, yesterday. A Southern Command spokesman said that Daykin was charged with conduct to the prejudice of good order and military discipline in not attempting the physics paper which he had been warned that he would have to take.—*The Times*, July 14, 1959.

" Physics Graduate/tennis player, seeks position which would enable him to pursue a career in tennis.—Write Box G. "—*The Times*.

Reviews of Books

THE TWO CULTURES AND THE SCIENTIFIC REVOLUTION

By C. P. Snow

London: Cambridge University Press. Pp. 51. *Price 3s. 8d.*

The widening gulf between scientists and those educated in and through the arts, and the need for a broadening of education generally, is the continuing theme of many addresses. Sir Charles Snow who, as scientist and writer, has lived and worked successfully in both fields, tells us in this Rede Lecture that: " The separation between the scientists and non-scientists is much less bridgeable among the young than it was even thirty years ago. Thirty years ago the cultures had long ceased to speak to each other: but at least they managed a kind of frozen smile across the gulf. Now the politeness has gone, and they just make faces." He has some profound things to say about the polarization of the intellectual life of society, and the consequent impoverishment of both scientist and non-scientist.

Turning to the reasons for the existence of the two cultures, he analyses the attitude intellectuals had to the industrial revolution and their lack of comprehension of what was happening. He points out:

" Almost none of the talent, almost none of the imaginative energy, went back into the revolution which was producing wealth. The traditional culture became more abstracted from it as it became more wealthy, trained its young men for administration, for the Indian Empire, for the purpose of perpetuating the culture itself, but never in any circumstances to equip them to understand the revolution or take part in it. Far-sighted men were beginning to see, before the middle of the nineteenth century, that in order to go on producing wealth, the country needed to train some of its bright minds in science, particularly in applied science. No one listened. The traditional culture didn't listen at all: and the pure scientists, such as there were, didn't listen very eagerly."

And in this century, in our own day, an even more prodigious change has taken place, the scientific revolution, bringing with it the industrial society of electronics, atomic energy and automation, and all the attendant problems of personal relations within it. How are we coping with all this ? Are we still thinking that applied science is an occupation for second-rate minds ? Are other countries, U.S.A. and U.S.S.R., doing better ? " In educational tactics, we are often more gifted than they are. In educational strategy, by their side we are only playing at it."

Indeed, we are doing nowhere enough ; one outstanding need is to produce many more educated to the level of a general or pass degree. " As the scientific revolution goes on—they will be required in thousands and thousands, and they will need all the human development that university education can give them."

Finally, he turns to what he calls the main issue of the scientific revolution—the division of the world into rich and poor countries. This, now it is appreciated by the poor, cannot last long ; it is essential that the West should help to speed up the transformation. " If we are short-sighted, inept, incapable either of good-will or enlightened self-interest," then the gap " may be removed to the accompaniment of war and starvation ; but removed it will be." Capital is needed, but also men—" trained scientists and engineers adaptable enough to devote themselves to a foreign country's industrialization for at least ten years out of their lives." This is an assignment of no small magnitude or minor significance for the future of the world.

The call to rethink our education recurs again and again ; " . . . for the sake of the poor who needn't be poor if there is intelligence in the world, it is obligatory for us and the Americans and the whole West to look at our education with fresh eyes."

No educationalist can read this lecture without being perturbed.

J. Topping.

ISAAC NEWTON'S PAPERS AND LETTERS ON NATURAL PHILOSOPHY, AND RELATED DOCUMENTS

Edited by I. Bernard Cohen and Robert E. Schofield

London: Cambridge University Press. Pp. xiii + 501. Price 70s.

" The intention of the present volume," says the Preface to this book, " is to bring together for the first time Newton's scattered papers and letters on natural philosophy (excluding mathematics, pure theology, and biblical chronology) as they were actually available *in print* during most of the 18th century, that is, prior to Horsley's edition of Newton's works in 1779-1785. Newton's two major books on physical science, the *Principia* and the *Opticks*, are to-day readily accessible, and in print; this volume complements them by placing in the hands of students all of Newton's related publications issued during his lifetime or soon after his death. The *Principia*, the *Opticks*, and the papers collected in this volume thus represent the complete corpus of Newton's writings on physical science that actually influenced the scientists and thinking men of the " Age of Newton "; the *Optical Lectures*, however interesting, were of less importance in conditioning the advance of science or moderating the general climate of opinion on the frame of the universe or the mechanism of nature . . . each document is reproduced in facsimile from the original publication; a facsimile is provided of a standard translation into English of those documents which are in Latin. Since many of Newton's communications are letters, as was customary in the 17th and 18th centuries, there have also been included facsimiles of the printed letters and documents written by others that were the occasion of each of Newton's communications. In every case, the page numbers of the originals have been kept, so that the scholar will have available to him in facsimile the actual pages of many rare works which are not to be found in all libraries, and certainly not on the shelves of students who wish to study the development of physical thought in the age of Newton."

The material written by others includes Bentley's *Confutation of Atheism*, based on Newton's four letters to him (which of course are provided), Halley's Review of the *Principia* and discourse prepared for King James II on " The true Theory of the Tides," and Fontenelle's *Éloge*, the first biography of Newton and for long the main source of information about his personal history and character. As well as a general Introduction by the Editor, Professor I. Bernard Cohen, each section contains a prefatory article by an authority on the subject. Thus Thomas S. Kuhn writes on Newton's Optical Papers; Marie Boas on his work in chemistry, atomism, the aether, and heat; William B. Todd and Perry Miller on the Bentley material; Robert E. Schofield on Halley and the *Principia;* and Charles Coulston Gillispie on Fontenelle and Newton. Appended are comments by Robert E. Schofield on Birch's *History of the Royal Society* and an index to its references to Newton.

It is superfluous to say that this volume will be invaluable to all who wish to study the work and the personality of the greatest of all scientists, and impossible to avoid saying so. Our debt to Professor Cohen and his collaborators is immense. The work must be hailed as the most important source-book in the history of science to be made generally available for many years. Comment on the problems raised by the documents and discussed in the prefatory notes could be endless and would necessarily be inconclusive, yet it would be ungracious not to say something by way of acknowledgment of the contemporary as well as the historical importance of the book. The following brief remarks on the vexed question of hypotheses and Newton's views and practice concerning them, on which more than one of the writers animadverts, are offered accordingly.

The celebrated " hypotheses non fingo " passage runs thus: " But hitherto I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypotheses; for whatever is not deduced from the phenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy." It is clear that the word " hypothesis," which causes so much perplexity, can be eliminated from this assertion, which then becomes : " I propose nothing that is not deduced from the phenomena; such things have no place in experimental philosophy." It would be difficult to convict Newton's practice of inconsistency with this statement. It can be read as excluding all things *not deduced* from the phenomena, or all things not deduced from *the phenomena*. The former are exemplified by the " mere names " which stand for the phenomena but for nothing extracted from them—" such Qualities," as Newton wrote else where, " as [the Aristotelians] supposed to lie hid in bodies, and to be the unknown causes of manifest effects." The latter included such general principles as circularity of planetary motions, which are indeed deduced, but from supposed rational necessity and not from phenomena. Both abuses were common in Newton's day, and, though usually disguised, are only too active in ours. But there is nothing at all in the statement to proscribe such " hypotheses " as that of light corpuscles for example, which are certainly deduced from the phenomena.

It need only be added that the production of the book is worthy of the material which it contains.

HERBERT DINGLE

TURNING POINTS IN PHYSICS

By R. J. Blin-Stoyle, D. Ter Haar, K. Mendelssohn, G. Temple, F. Waismann and D. H. Wilkinson. Edited by A. C. Crombie

Amsterdam : North-Holland Publishing Company. Pp. 192. Price 20s.

This book is a collection of addresses given at Oxford under the auspices of the department of History and Philosophy of Science. It describes the character of certain leading ideas that have guided or still guide physicists in their attempts to formulate general laws of nature, e.g., field theory, probability, relativity, causality, etc. The title is perhaps a little misleading but nowadays, when any occasion seems to be describable as a " juncture," an extension of the misnomer is of no great importance. The chapters are of very unequal length, that on causality being more than twice as long as any of the others and nearly five times as long as the shortest, on the quantum nature of matter and radiation. Evidently it would be a great mistake to interpret the space given to a subject as a measure of its importance.

As a description, for the non-specialist, of physical ideas, the book can be highly recommended. All the authors write clearly, without allowing consideration of details to obscure the broad general ideas that they set out to explain. A few factual errors on historical points do not seriously mar the general accuracy of the picture presented, and the book should be specially useful to those, whether physicists or not, who in the complexity of modern research are in danger of missing the wood for the trees. The last chapter, " Towards New Concepts," is as clear, concise and comprehensive an account of the bewildering interrelations of the many " fundamental particles " now supposed to function as one may find anywhere.

As a contribution to the history and philosophy of science, however, the book presents a very different aspect. The outstanding service which this subject can render in the present age—and indeed in any age—is to redeem us from the original sin of supposing that what we think is " true " and what our forbears thought was " false," It should enable us to detach ourselves from the particular moment at which we happen to stand, and see the course of scientific history as a continuous process in which the ideas of " to-day " bear to those of 2059 somewhat the same relation as the ideas of 1859 bear to ours. If we could catch that vision it would from many a blunder free us and foolish notion. In the scientific pilgrimage we are necessarily at one point —the Valley of Humiliation or Vanity Fair or whatever it may be—but we should be able to understand our position well enough to know that that point is not the Celestial City.

When we do that in physics we realize that the continually progressive element of the process is the degree of interrelatedness of our experiences that we are able to recognize. No matter how the superficial aspects of physics changes, at each stage something that previously appeared independent is brought into relation with something else. The particular concepts in terms of which we express the growing system of relations may change without rhyme or reason; that matters not at all. Metals are transmutable, then they are not, then they are again: light is an antenna, then a particle, then a wave, then a particle again: there are several ethers, then there is only one, then there is none, then there is a sort of ether. So it goes on. And all the time more and more phenomena are being brought into relation with one another.

The besetting sin of this book is that it obscures all this by first tacitly assuming that the " turning points " are the fundamentally important things instead of being merely tools, and then less tacitly indicating that we have now reached the last of them. The first fault is general, the second very unequally in evidence in the various contributions. " One has a continuous evolution of physical theory " (p. 5). " Entropy essentially measures the degree of disorder in a physical system " (p. 50)—a most inessential visualization which has probably done much more harm than good. " It had been shown by a great number of different experiments that this charge could not be " (instead of " had not been ") " subdivided " (p. 60). " The final answer to the problem of matter waves was furnished . . ." (p. 60). " The fact that truth is statistical " (p. 67). " The experimental fact of the invariancy of the speed of light when measured by observers in relative motion " (p. 78); this " fact " is a deliberate and avowed assumption, transmuted into a " fact " by time and not by experiment. " ' You mean physicists have not yet discovered the true causes ? ' No ; I mean causality has definitely come to an end " (p. 84). " The uncertainty principle marks the final break with the past " (p. 137).

How fortunate we are to be living at a time when the " glib extrapolation " (p. 55) of the classical physicists has been outmoded ! However, there is one point on which the uninstructed reader might feel slight perplexity. He will not, of course, expect different writers to agree on all points, yet he may well be excused for supposing them to take a common view on the fundamental condition of all science. But "scientific activities are based on a faith which states essentially that nature . . . shews us a *pattern* which is meaningful" (pp. 30-1), and "Nature is not bound by reasonableness" (p. 163). Perhaps however "Nature" in the second passage is intended to stand for "the mathematical physicist's description of nature," and in that case criticism is silenced.

HERBERT DINGLE.

ON NUCLEAR ENERGY—ITS POTENTIAL FOR PEACETIME USES

By D. J. Hughes

Harvard University Press. London: Oxford University Press. Pp. xi + 263. Price 30s.

The author of this book is a nuclear physicist on the staff of the Brookhaven National Laboratory and the book, as he explains in the preface, has grown out of numerous lectures given by him to non-technical audiences over the post-war years. There have been many popular accounts of the basic principles and historical development of the nuclear energy industry, some of which, like the original Smyth Report, were both accurate and excellently written. The physical information given in the present book appears to be accurate enough but the style is a mixture of chattiness, unnecessary repetition, and downright padding which makes it very difficult to read the book with any enjoyment. The lectures may have been excellent but they should have been put into a less diffuse form before publication.

The fundamentals of fission, fusion and the chain reaction are dealt with in the first few chapters and the main part of the book is devoted to the applications of nuclear power and of the radiations and radioactive materials derived from reactors.

The political and economic aspects of nuclear energy development are given lengthy treatment, not unnaturally, from a very American point of view ; but making due allowance for this, long sections of the book are too much like a statement from some official in a public relations department.

In a chapter entitled "The International Atom" an account is given of developments in other parts of the world and the author describes (in the first person singular) some of his travels through the wilds of Europe, including Russia. (Russian scientists collectively are usually referred to as "the Soviets.") He seems to wish to be fair—indeed sympathetic—to these other countries but alas succeeds only in being patronizing.

A final chapter on fusion is based almost entirely on the Kurchatov lecture given at Harwell in 1956.

J. W. BOAG.

TECHNICAL REPORT WRITING

By J. W. Souther

New York : John Wiley & Sons Inc., London : Chapman & Hall Ltd. Pp. xi + 70. Price 24s.

This little book by Professor Souther, who is Associate Professor of Humanistic and Social Studies and Assistant Dean, College of Engineering, in the University of Washington, is a general dissertation on the preparation of a wide variety of Reports, covering normal business letters, memoranda, routine reports requiring answers to a standard questionnaire, reports in the form of letters, articles and formal reports.

There are five chapters—an introduction dealing with general principles, and chapters on what the author regards as the four processes involved. These are Analysis, dealing with the aim of a Report and what it is desired to achieve ; Investigation, dealing with what should go into the Report and how the material may be obtained ; Design, dealing with the general lay-out and make-up of the Report so as to achieve its desired purpose, and Application, dealing with putting the Report into words.

Professor Souther has taken the majority of his examples from the Engineering field, but his book should prove helpful in the preparation of Reports in other fields. The style is somewhat discursive but the treatment is thorough; perhaps more attention on the part of the Author to his own plea for clarity and conciseness would have produced a more useful, though a much shorter, volume. There are many helpful suggestions on the mechanics of report writing, particularly in the chapter on Investigation, and it will no doubt serve to remind the potential report writer of the many things which will help him to convey to his reader the information he wishes to convey and in a form that will help him to achieve the result he desires. As the author says, "The two most fundamental requirements of successful communication are (1) that the writer knows clearly and specifically what it is he is going to say and (2) that he states it in such a way that the reader fully understands him" ; this book will assist achieving these two objectives. But on the author's other contention, which will be generally accepted, that "clear thinking is the basis of clear writing" it is doubtful if his book will assist very much.

The book is excellently produced and bound in paper board covers.

N. LAYCOCK.

PRACTICAL METROLOGY

By K. J. Hume and G. H. Sharp

London : Macdonald & Co. (Publishing) Ltd. Pp. vii + 87. Price 10s. 6d.

Like its predecessors published respectively in 1953 and 1956, Volume 3 in this planned series of four instructional manuals describes twelve laboratory experiments in engineering metrology. These experiments, which are more advanced than those included in the earlier volumes, correspond to actual examples of inspection and verification work arising in the practice of precision engineering. The descriptions include complete instructions for the performance of the experiments together with notes on the recording and assessment of the results of measurement. As in the earlier volumes, a good feature is the reference to relevant B.S.I. specifications to guide assessment.

The experiments include the measurement of an angular plate gauge, the effective diameter of a ring screw gauge and the included angle of a taper plug gauge (introducing the use of the autocollimating telescope) ; setting and calibrating an engineer's block spirit level ; calibrating a dial gauge, a dividing head or table and a divided circle ; comparing two slip or block gauges using the N.P.L. level comparator ; testing a straight-edge and the flatness of a surface plate ; and checking the involute profile of a spur gear.

The manual is well produced and includes a few illustrations and diagrams. It is particularly recommended for the use of teachers and students of precision engineering and applied physics.

H. Barrell.

STUDIES IN GEOMETRICAL OPTICS

By A. Pitchford

London : Macdonald & Co. (Publishing) Ltd. Pp. vii + 221. Price 32s. 6d.

This is a general textbook covering most of the principles of geometrical optics required by students up to first year University standard. It has obviously been written with a bias towards technology rather than to pure science, and therefore may fulfil a useful function at the present time. In the Preface it is said to have been prepared for three classes of students (*a*) G.C.E. " A " level and Scholarship students, (*b*) first year University and Technical College students, (*c*) students in ophthalmic optics. Apart from these groups, however, it would be a suitable book to recommend to research workers who are not physicists but who need to learn something about optical systems, and to those who are preparing to be instrument-technologists in the optics industry.

The plan of the book makes it specially helpful to the student working alone, and at every stage there are well-chosen worked examples which go a long way towards clarifying arguments without the need to refer to a tutor. It is copiously illustrated, and the diagrams —although at first sight a little untidy—do in fact serve their purpose quite well. The sign convention used is that often referred to as the New Cartesian, so that the sign given to the focal length of lenses agrees with that used by ophthalmic opticians.

The chapter headings give a clear indication of the contents ; they are :—

1. Refraction at Spherical Surfaces
2. The Thin Lens
3. Spherical Mirrors
4. Co-axial Systems of Spherical Surfaces
5. The Thick Lens in Air
6. Two Thin Separated Lenses
7. The Human Eye
8. The Seidel Aberrations
9. Chromatic Aberration
10. Microscopes and Telescopes.

The chapter on Co-axial Systems of Spherical Surfaces, which leads naturally into the chapters on thick lenses and two thin separated lenses, is particularly valuable. All the arguments are given in great detail and the worked examples are selected so as to illustrate fully the various special and general applications. In addition to the worked examples each chapter is followed by sets of problems to which answers are supplied. There is also a rather odd collection of examination questions which in the Preface are claimed to be from " recent examination papers," but in fact, as far as the Advanced level questions are concerned, range from 1927-1949 !

There have been many optical textbooks produced recently, both in England and in America, and it is inevitable that there should be much common material; one is bound to wonder if they are all justified. The treatment and subject matter of this book, however, are sufficiently " different " to make its publication worthwhile.

C. A. Taylor.

READING GERMAN FOR SCIENTISTS

By Hans Eichner and Hans Hein

London : Chapman & Hall Ltd., Pp. xi + 207. Price 30s.

The title of the book is perhaps misleading because the volume gives the student a sound insight into German grammar, a thing often sketchily done in other scientific German readers. One is introduced from the start to the scientific vocabulary and no time is wasted with unnecessary words. This is a good thing as it enables the student to come to grips with simple scientific passages from the start. When he has learnt the vocabulary and grammar contained in the book he should be able to translate any German passage he may come across, although a dictionary will no doubt be needed.

When a certain part of grammar has been explained, illustrative sentences are given to show its usage in the German. The authors have dealt with some of the difficult points of grammar at length while simpler concepts are passed over fairly rapidly. Simple English sentences have also been given for translation into German and these would have proved more valuable as a means of checking progress if a key had been provided.

The authors are to be congratulated on their choice of interesting historical and modern passages for translation. The book is neatly set out and some thought has obviously been given to the grading of the exercises and the standard of difficulty of the various passages. It has much to commend it and should prove very useful both to beginners and to those who have some knowledge of German. The book is more comprehensive than most of the others on this subject and it should be welcomed by any scientist who has to deal with German literature.

J. M. Corsan.

Group News

Education Group Summer Meeting

The Annual Summer Meeting of the Education Group was held this year at Cambridge on Saturday, July 18.

In spite of the fact that the Group visited Cambridge in 1955, and the early start required, the visit was exceedingly popular. Nearly a hundred members and their guests attended. It is a pleasant change to have to ask restaurants and bus companies to arrange for twice the number originally booked. The principal difficulty of the visit was the strain put upon our hosts at the Cavendish Laboratory, in providing enough guides to enable the party to be broken up into small groups and so enable everyone to see all that was to be seen and to hear all that was to be heard.

Under the circumstances, the Cavendish Laboratory rose to the occasion extremely well, in spite of the fact that they were in the middle of a Summer School on solid state physics. For this School they had expected 20 students and had to deal with 90. Our party was given a very interesting time in the Crystallography department the scanning micro-analyser was demonstrated. Its use in quantitative chemical analysis was explained and illustrated by reference to the problem of certain cracks developing in a piece of steel. These proved to be due to the percentage of nickel going up from a general average of 4% to local concentrations of 50% where the cracks developed.

Professor Mott gave a talk on the research work being done in his laboratory, the educational side and the courses for the Triposes. He emphasized the difficulty of doing all they wanted to do in a three year course. He gave us his thoughts upon the advantages and disadvantages of their teaching system, the problems of the different grades of student, the necessity for students to be able to express themselves clearly and the question of liberal studies. In this connection, he stated that a formal lecture was given every Monday morning during term on subjects ranging from architecture to the ballet. These lectures were well attended but in his view they were hardly necessary in such a place as Cambridge.

A group listening to Dr. Martin Ryle

section and heard and saw all about the new properties that can be obtained from aluminium crystals with different bonding. The Van de Graaff electrostatic generator, its principle, construction, control and applications were explained and our members had a good look at the machine.

The Electron Microscopy section was also visited and the work done with the microscope was explained. Magnifications can now be obtained up to a million times with all the resolution of which use can be made. The two principal uses are the applications to solid state physics and to virus structures. The party had this clearly explained and were able to see the influenza virus on the screen of the instrument. In the same

After a good lunch, the party visited the Radio-Astronomy Observatory. The party were welcomed by Martin Ryle who gave an introductory talk on radio-astronomy in general and upon the advantages and results of the methods he was using in particular. A tour of the telescopes on the site was made and a very full and interesting explanation given. All questions were answered with the expert knowledge of one of our leading radio-astronomers who appears to be a highly skilled engineer as well.

A full explanation of aperture synthesis, the printing of information received directly upon tape in the form required by the electronic computor, the interferometer telescopes, the measurement of the diameter of radio-sources, location and plotting of radio stars to the accuracy required for optical investigation by the Mount Palomar 200-inch reflecting telescope—all this and very much more, was extremely well described. Fortunately the weather was perfect for such an open-air visit.

After this, members were able to have tea and see a little of Cambridge and its colleges before leaving for home by train or car.

Mr. G. W. Warren, Education Group Chairman

PLAN OF MULLARD OBSERVATORY
SHOWING POSITIONS OF RADIO TELESCOPES

Dr. Martin Ryle giving an introductory talk

Many thanks are due to Dr. A. D. I. Nicol for his great help in organizing what everyone agrees was one of the most successful and enjoyable Summer Meetings of this Group.

T. H. TYLER.

Forthcoming Institute Meetings

THE following is the list of Institute meetings so far arranged for the first half of the 1959-60 session. Members of all grades may attend any of the meetings, whether or not they belong to the Branch or Group concerned. Where it is indicated that tickets or application forms are necessary early application should be made.

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Sept. 16 to 18	**Birmingham** The University		Annual Conference		Stress Analysis
Sept. 21	**Manchester** College of Science and Technology	Dr. R. A. Smith (*Royal Radar Establishment, Malvern*)	**Semiconductors and infra-red spectroscopy**	7.00 p.m.	Manchester and District
Sept. 22 to 24	**Sheffield** The University		Residential Conference on **Some aspects of magnetism** This Conference is open to all interested but registration is necessary. Full details may be obtained from the Secretary of the Institute.		
Sept. 30	**Birmingham** The University	Professor R. E. Peierls, C.B.E., F.R.S. (*University of Birmingham*)	**Mirror symmetry and the concept of parity in physics**	6.30 p.m.	Midland

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Oct. 2 and 3	**Baldock** Services Electronics Research Laboratory		Conference on **Noise in electronic devices** Registration is necessary. Full details may be obtained from the Secretary of the Institute.		Electronics
Oct. 6	**Wembley** Research Laboratories, The General Electric Co. Ltd.		Visit to the Research Laboratories of The General Electric Co. Ltd. Admission by ticket only on application to the Secretary of the Institute. Members of the London and Home Counties Branch have received full details.	2.30 p.m.	London and Home Counties
		Dr. J. Woods, A.Inst.P. (*Research Laboratories, The General Electric Co. Ltd., Wembley*)	The visit will be followed by a lecture on **The role of solid state physics in modern technology**	5.15 p.m.	
Oct. 7	**London** The Institute's House	Dr. B. P. Dudding, M.B.E., F.Inst.P. (*Research Laboratories, The General Electric Co. Ltd., Wembley*)	**The scientist in the factory**	6.00 p.m.	Education
Oct. 8	**Liverpool** The University	Dr. R. L. F. Boyd (*University College, London*)	**Space research**	7.00 p.m.	Liverpool and North Wales
Oct. 14	**Newcastle-upon-Tyne** King's College	Dr. H. M. Finniston *C. A. Parsons Co. Ltd., Nuclear Research Centre*)	**The effects of irradiation on reactor materials**	6.15 p.m.	North Eastern
Oct. 16	**St. Andrews** The University	Dr. G. Wyllie, F.Inst.P. (*University of Glasgow*)	**The new realism of physical theory**	5.00 p.m.	Scottish
Oct. 16	**London** The Institute's House	Mr. D. G. Christie, A.Inst.P. (*Aluminium Laboratories Ltd., Banbury*)	**Propagation of elastic waves in plates**	6.00 p.m.	Non-Destructive Testing
Oct. 16	**Cardiff** University College	Mr. S. Rees Jones, F.Inst.P. (*Courtauld Institute of Art, London*)	**Physics and the artist**	6.15 p.m.	South Wales
Oct. 19	**Manchester** The University	Mr. M. G. Rusbridge (*Atomic Energy Research Establishment, Harwell*)	**Thermonuclear research at Harwell**	7.00 p.m.	Manchester and District
Oct. 20	**London** The Institute's House	Dr. F. Kröger (*Philips Electrical Ltd., Eindhoven*)	**The role of chemistry in solid-state physics**	5.30 p.m.	Electronics
Oct. 21	**Hull** The University	Dr. R. A. Smith (*Royal Radar Establishment, Malvern*)	**Molecular amplifiers and oscillators** (**Masers**)	6.30 p.m.	Yorkshire
Oct. 21	**Birmingham** Exchange and Engineering Centre		Branch Annual General Meeting followed by a lecture on	6.30 p.m.	Midland
		Mr. F. Oldham, J.P., F.Inst.P. (*Hinckley Grammar School, Hinckley, Leics.*)	**Early nineteenth century physics with special reference to Thomas Young**	7.00 p.m.	
Oct. 26	**Aberdeen** The University	The President of the Institute, Sir George Thomson, Hon.F.Inst.P, F.R.S. (*University of Cambridge*)	**Thermonuclear processes**		Scottish
Oct. 27	**Glasgow** The University	The President of the Institute, Sir George Thomson, Hon.F.Inst.P., F.R.S. (*University of Cambridge*)	**Thermonuclear processes**	7.15 p.m.	Scottish
Oct. 29	**London** The Institute's House	Professor G. O. Jones (*Queen Mary College, London*)	**New uses for low temperatures**	6.00 p.m.	London and Home Counties
Oct. 30	**Bristol** The University	Professor J. D. Bernal, F.Inst.P., F.R.S. (*Birkbeck College, London*)	**The structure of liquids**	7.00 p.m.	South Western

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Nov. 5	**Bangor**	Speaker and subject to be announced later		5.45 p.m.	Liverpool and North Wales
Nov. 6	**London** The Institute's House	Mr. R. D. Moore, A.Inst.P. (*Guy's Hospital Medical School, London*)	**The role of physics in the investigation and treatment of heart disease**	6.00 p.m.	Non-Destructive Testing
Nov. 6	**Newcastle-upon-Tyne** King's College	Prof. H. S. W. Massey, F.R.S. (*University College, London*)	**The scientific uses of rockets and satellites**	6.15 p.m.	North-Eastern
Nov. 9	**Edinburgh** The University	Mr. R. M. Sillito, F.Inst.P. (*University of Edinburgh*)	**Light waves, radio waves and photons**	7.15 p.m.	Scottish
Nov. 10	**Glasgow** The University	Mr. R. M. Sillito, F.Inst.P. (*University of Edinburgh*)	**Light waves, radio waves and photons**	7.15 p.m.	Scottish
Nov. 10	**London** The Institute's House	Dr. F. C. Champion, F.Inst.P. (*King's College, London*)	**Electronic properties of diamonds**	5.30 p.m.	Electronics
Nov. 12	**Liverpool** Chadwick Laboratory, The University		A social evening. Details will be sent to branch members.		Liverpool and North Wales
Nov. 13	**Exeter** The University	Professor M. H. L. Pryce, F.R.S. (*University of Bristol*)	**Clocks, space travel and relativity**	5.30 p.m.	South Western
Nov. 13 and 14	**London** The Institution of Civil Engineers		Conference on **Structure analysis** and **Apparatus and experimental techniques**	10.00 a.m.	X-ray analysis
		Professor P. P. Ewald, F.Inst.P., F.R.S. (*Polytechnic Institute of Brooklyn, U.S.A.*)	Evening discourse on **Crystallography in the past and the future**	8.00 p.m.	
		Registration is necessary. Full details may be obtained from the Secretary of the Institute.			
Nov. 16	**Manchester** College of Science and Technology	Dr. R. L. F. Boyd (*University College, London*)	**High altitude research during the International Geophysical Year**	7.00 p.m.	Manchester and District
Nov. 17	**London** The Institute's House	Dr. R. L. F. Boyd (*University College, London*)	**Some techniques and results of space exploration**	6.00 p.m.	London and Home Counties jointly with Electronics
Nov. 18 (provisional)	**Aberdeen** The University	Dr. G. Wyllie, F.Inst.P. (*University of Glasgow*)	**Dielectric polarization and absorption**		Scottish
Nov. 20	**Swansea** University College	Dr. J. G. Dawes, F.Inst.P. (*Safety in Mines Research Establishment, Sheffield*)	**Physics and the Safety in Mines Research Establishment**	5.15 p.m.	South Wales
Nov. 20	**Bournemouth** Municipal College of Technology and Commerce	Dr. R. L. F. Boyd (*University College, London*)	**Some techniques and results of space exploration**	7.30 p.m.	London and Home Counties jointly with the Mid-Southern Counties Section of the Royal Institute of Chemistry
Nov. 23	**Edinburgh** The University	Professor H. A. Brück, F.R.S.E. (*Astronomer Royal for Scotland*)	**Structure and evolution of the galaxy**	7.15 p.m.	Scottish
Nov. 24	**Glasgow** The University	Professor H. A. Brück, F.R.S.E. (*Astronomer Royal for Scotland*)	**Structure and evolution of the galaxy**	7.15 p.m.	Scottish
Nov. 25	**London** The Institute's House	Mr. J. F. Coales, O.B.E., F.Inst.P. (*University of Cambridge*)	**Education for automation**	6.00 p.m.	Education

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Dec. 2	**Durham** Science Laboratories	Professor C. C. Butler, A.Inst.P. (*Imperial College of Science and Technology, London*)	**The British national hydrogen bubble chamber project**	5.30 p.m.	North-Eastern
Dec. 2	**Sheffield** The University	Professor S. Tolansky, F.Inst.P., F.R.S. (*Royal Holloway College, Egham*)	**The micro-structures of surfaces**	5.00 p.m.	Yorkshire
Dec. 3	**Liverpool** The University	Mr. E. W. Walker (*Atomic Weapons Research Establishment, Aldermaston*)	**High speed photography**	7.00 p.m.	Liverpool and North Wales jointly with Students' Physical Society
Dec. 4	**Bristol** College of Technology	Dr. R. L. F. Boyd (*University College, London*)	**Space research**	7.00 p.m.	South Western
Dec. 4	**London** The Royal Society of Tropical Medicine and Hygiene	Dr. H. Kaiser (*Institut für Spektrochemie und Angewandte Spektroskopie*)	Group Annual General Meeting followed by a lecture on **Time-resolved spectroscopy**	2.15 p.m. 3.00 p.m.	Applied Spectroscopy
Dec. 7	**Edinburgh** The University	Dr. G. Wyllie, F.Inst.P. (*University of Glasgow*)	**The new realism of physical theory**	7.15 p.m.	Scottish
Dec. 8	**Glasgow** The University	Dr. G. Wyllie, F.Inst.P. (*University of Glasgow*)	**The new realism of physical theory**	7.15 p.m.	Scottish
Dec. 9	**London** The Institute's House	Sir Edward C. Bullard, F.R.S. (*University of Cambridge*)	**Geological time**	6.00 p.m.	London and Home Counties
Dec. 10	**Birmingham** Regent House	Professor N. F. Mott, F.Inst.P., F.R.S. (*Cavendish Laboratory, Cambridge*)	**Recent work on dislocations**	6.30 p.m.	Midland
Dec. 11	**London** The Institute's House	Mr. J. F. Sayers, Grad.Inst.P. (*Atomic Energy Research Establishment, Harwell*)	**The ultrasonic camera—an alternative approach to ultrasonic testing**	6.00 p.m.	Non-Destructive Testing
Dec. 11	**Cardiff** University College	Dr. J. A. Pople (*National Physical Laboratory, Teddington*)	Branch Annual General Meeting followed by a lecture on **Nuclear magnetic resonance in liquids**	6.15 p.m.	South Wales
Dec. 14	**Manchester** The University	Mr. R. H. Litherland (*School of Art, Salford*)	**The aesthetic design of scientific instruments**	7.00 p.m.	Manchester and District
Dec. 15	**London** The Institute's House	Mr. K. G. Freeman (*Mullard Research Laboratory, Salfords*)	**Tubes for colour television**	5.30 p.m.	Electronics
1960					
Jan. 11	**London** The Institute's House	Professor J. G. Wilson, F.Inst.P. (*University of Leeds*)	**The problem of primary cosmic radiation**	6.00 p.m.	London and Home Counties
Jan. 14	**Liverpool** The University	Dr. E. Mendoza (*University of Manchester*)	**Electronic applications of superconductivity**	7.00 p.m.	Liverpool and North Wales
Jan. 15	**Bristol** The University	Mr. A. J. Garratt, M.B.E., A.Inst.P. (*International Scientific Research Exhibitions Ltd., London*)	**Science on television**	7.00 p.m.	South Western
Jan. 15	**Newport** College of Technology	Dr. J. W. Menter, F.Inst.P. (*Tube Investments Research Laboratories, Cambridge*)	**The microstructure of crystalline solids**	6.00 p.m.	South Wales
Jan. 18	**Manchester** The University	Dr. J. B. Birks, F.Inst.P. (*University of Manchester*)	**Recent developments in scintillation counting**	7.00 p.m.	Manchester and District
Jan. 20	**London** The Institute's House	Mr. H. J. Dunster (*Health and Safety Branch, United Kingdom Atomic Energy Authority*)	**Health physics**	6.00 p.m.	Education

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON JULY 7, 1959

An asterisk (*) indicates transfer from another grade

FELLOWS (9)

*Bell, Joseph Charles, B.Sc., Principal Scientific Officer, U.K. Atomic Energy Authority, Windscale, Cumberland.

*Evans, Samuel Islwyn, B.Sc., Ph.D., Divisional Chief Scientist, National Coal Board, Cardiff.

*Giles, Cyril George, B.Sc., Principal Scientific Officer, Department of Scientific and Industrial Research, Harmondsworth, Middlesex.

*Hawkins, Arthur Ernest, B.Sc., Lecturer, Royal Veterinary College, University of London.

*Haywood, Colin Allen, M.Sc., Senior Lecturer, University of Leicester.

Nederbragt, Gerrit Willem, Ph.D., Physicist, Koninklijke Shell-Laboratories, Amsterdam.

*Russell, Raymond Laycock, D.Sc., Reader in Electrical Engineering, University of Bristol.

*Wass, Charles Alfred Alan, B.Sc., Ph.D., Deputy Director, Safety in Mines Research Establishment, Sheffield, Yorks.

*Widdowson, Arthur Everard, B.Sc., Ph.D., Principal Scientific Staff, The General Electric Co. Ltd., Wembley, Middlesex.

ASSOCIATES (53)

Beynon, Leslie Raymond, B.Sc., Physicist, British Petroleum Co. Ltd., Sunbury-on-Thames, Middlesex.

Birss, Ian Robertson, B.Sc., Ph.D., Assistant Lecturer, University of Glasgow.

Bogle, Gilbert Stanley, M.Sc., M.A., D.Phil., Senior Research Officer, C.S.I.R.O., Chippendale, New South Wales, Australia.

*Bradley, Edward Frank, B.Sc., Experimental Officer, Atomic Weapons Research Establishment, Harwell, Berks.

Castle, John Cecil, M.Sc., Research Engineer, Electric and Musical Industries Ltd., Hayes, Middlesex.

*Coleman, Colin Roy, B.Sc., Physicist, Dunlop Rubber Co. Ltd., Fort Dunlop, Birmingham.

Coogan, Clive Keith, M.Sc., Ph.D., Senior Research Officer, C.S.I.R.O., Melbourne, Victoria, Australia.

Crawford, James William, B.Sc., Senior Lecturer, Croydon Technical College, Surrey.

Dawber, James, B.Sc., Senior Physics Master, Wade Deacon Grammar School (Boys), Widnes, Lancs.

*Derrick, Kathleen Mary, B.Sc., Teaching Assistant, University of Pittsburg, U.S.A.

Dickson, John Home, M.Sc., Senior Experimental Officer, Admiralty Research Laboratory, Teddington, Middlesex.

Dutta, Sachindra Nath, M.Sc., Ph.D., Lecturer, University of Lucknow, India.

*Eeles, Wilfred Trefor, M.Sc., Senior Scientific Officer, U.K. Atomic Energy Authority, Foulness, Essex.

*Ellingham, Bruce, B.Sc., Ph.D., Development Physicist, Smith & Nephew Textiles Ltd., Brierfield, Lancs.

Goldman, Kazimierz, B.Sc., Senior Physicist, British Oxygen Research & Development Ltd., London.

Herman, Philip Harold, B.A., Research Physicist, Mining and Chemical Products Ltd., Windsor, Berks.

Higham, Edgar John, M.A., Physicist, U.K. Atomic Energy Authority, Seascale, Cumberland.

Hinckfuss, Ian Charles, B.Sc., Scientific Officer, Weapons Research Establishment, Salisbury, S. Australia.

Hopkins, Brian John, B.A., Ph.D., Assistant Lecturer, University of Southampton.

Khan, Naeem Ahmad, M.A., M.Sc., Ph.D., Assistant Meteorologist, Pakistan Meteorological Service.

*Johnston, James Stewart, B.Sc., A.R.C.S., Senior Engineer, Decca Radar Ltd., Surbiton, Surrey.

*Lewis, Arthur Beesley, B.Sc., Research Officer, British Cotton Research Association, Shirley Institute, Didsbury, Manchester.

Lowthian, Brian Walker, B.Sc., Ph.D., Assistant Lecturer, Royal Technical College, Salford, Lancs.

McElhinny, Michael William, B.Sc., Ph.D., Lecturer, University College of Rhodesia and Nyasaland, Salisbury, S. Rhodesia.

*Macaulay, Ian James, B.Sc., Scientific Officer, Weapons Research Establishment, Salisbury, S. Australia.

Maidanik, Gideon, M.Sc., Ph.D., Senior Scientist, British Oxygen Research and Development Ltd., London.

*Marshall, Joseph, B.Sc., Group Leader, Smith's Aircraft Instruments Ltd., Cheltenham, Glos.

Mason, Walter Wright, B.Sc., Principal Lecturer in Science, Technical Teachers Training College, Bolton, Lancs.

*Metcalfe, Charles Sydney, B.Sc., Flight Trials Engineer, De Havilland Propellers Ltd., Stevenage, Herts.

*Morrison, Jeffrey, B.Sc., Electronics Engineer, English Electric Aviation Ltd., Preston, Lancs.

Oakeshott, David Francis, B.Sc., Section Head, Central Electricity Research Laboratories, Leatherhead, Surrey.

Orr, John Stewart, B.Sc., Senior Physicist, Western Regional Hospital Board, Glasgow.

Padgham, Charles Arthur, A.R.C.S., M.Sc., Ph.D., Senior Lecturer, Northampton College of Advanced Technology.

*Peacock, Norman, M.A., M.Sc., Ph.D., Research Fellow, University of Leeds.

*Pendleton, David James Lane, B.Sc., Assistant Chief Chemist, Aylesford Paper Mills, A. E. Reed & Co. Ltd., Maidstone, Kent.

Rausell-Colom, Jose Antonio, B.Sc., Ph.D., Research Officer, C.S.I.R.O., Division of Soils, Adelaide, S. Australia.

*Rout, Vivian Mary, M.Sc., Research Physicist, Associated Electrical Industries Ltd., Research Laboratory, Aldermaston, Berks.

*Scobie, James, B.Sc., Ph.D., Research Collaborator, University of Arkansas, U.S.A.

Scott, Bernard, B.Sc., Ph.D., Senior Lecturer, Hatfield Technical College, Herts.

Shaw, Anthony James Gagan, B.A., Assistant to Managing Director, W. Pickard & Co. Ltd., Sheffield, Yorks.

Shepanski, John Richard, M.Sc., Lecturer, University of New South Wales, Australia.

Silverleaf, David James, B.Sc., Ph.D., Lecturer, Brighton Technical College, Sussex.

Singh, Lakshman, M.Sc., Ph.D., Head of Physics Department, Yuvaraj Datt College, Lakhimpur Kheri, India.

Spector, Jack, B.Sc., Spectrographer, Imperial College of Tropical Agriculture, Trinidad, B.W.I.

Sreekantath, Gopala Menon, M.A., Professor of Physics, University College, Trivandrum, India.

*Starling, Peter Phillip, B.Sc., Spectographer, Applied Research Laboratories, Lausanne, Switzerland.

Surplice, Norman Alexander, B.Sc., Ph.D., Lecturer, University College of North Staffordshire, Keele, Staffs.

*Taylor, Joan Douglas, B.Sc., Physicist, Low and Bonar Ltd., Dundee, Scotland.

*Tozer, Bryan Allen, B.Sc., Ph.D., Research Fellow, Queen Mary College, London.

Twidle, George Geoffrey, A.R.C.S., M.Sc., Experimental Officer, National Physical Laboratory, Teddington, Middlesex.

Wadsworth, Nicolas John, B.Sc., Ph.D., Senior Scientific Officer, Royal Aircraft Establishment, Farnborough, Hants.

White, George, M.A., B.Sc., Experimental Officer, U.K. Atomic Energy Authority, Dounreay, Thurso, Caithness.

*Ziman, Geoffrey Charles, M.A., Project Leader, Marconi Instruments Ltd., St. Albans, Herts.

GRADUATES (28)

Bartlett, John Terence, B.Sc., Research Student, University of Bristol.

Bertioli, Michael Murray, B.Sc., Research Physicist, Tube Investments Technological Centre, Walsall, Staffs.

Chapman, Christopher John Stuart, B.A., Research Student, University of Oxford.

Coombe, Ronald Alan, B.A., M.Sc., Research Student, University of Birmingham.

Dewsberry, Roland, B.A., Research Student, University College of North Staffordshire, Keele, Staffs.

*George, Barbara Kay, B.Sc., Scientific Officer, Department of Supply, S. Australia.

*Gerrard, John Peter Duncan, B.A., Postgraduate Trainee, Standard Telephones and Cables Ltd., Harlow, Essex.

Gozna, Clive Frederick, B.A., M.Sc., Research Student, University College of North Staffordshire, Keele, Staffs.

Heath, Michael George, B.Sc., Student, Education Department, University of Exeter.

*Hilton, Sheila Valentine, B.Sc., Assistant Hospital Physicist, Royal Free Hospital, London.

*Hopkins, David Royston, B.Sc., Experimental Physicist, Nuclear Power Plant Co. Ltd., Knutsford, Cheshire.

Howes, John Alfred, B.Sc., Junior Research Assistant, Electrical Research Association, Leatherhead, Surrey.

Jackson, Peter Frederick, B.Sc., Assistant Lecturer, Nottingham and District Technical College.

Jebson, Gordon Walker, B.A., Physicist, Rolls Royce Ltd., Derby.

*Jones, Tudor Bowden, B.Sc., Research Student, University College of Swansea, Glamorgan.

*Kidd, Donald Ewing, B.Sc., Research Student, University of Birmingham.

Malone, Michael, B.A., Research Student, University of Southampton.

Mee, Christopher Hugh Barnard, B.A., M.Sc., Research Student, University College of North Staffordshire, Keele, Staffs.

Morgan, John Llewellyn, B.Sc., Junior Engineer, De Havilland Propellers Ltd., Hatfield, Herts.

Peach, Brian, B.A., Assistant Science and Maths Teacher, March Grammar School, Cambridgeshire.

Shepstone, Basil John, M.Sc., Doctorate Student, University of the Orange Free State, South Africa.

Skardhamar Torfinn, B.Sc., Postgraduate Student, University of Birmingham.

Smith, Donald, B.A., Research Student, University College of North Staffordshire, Keele, Staffs.

*Spanney, Kenneth David, B.Sc., Part-time Teacher of Science, Lowther Hall, Essendon, Victoria, Australia.

*Thomas, Delfryn, B.Sc., Research Student, Northern Polytechnic, London.

Williams, Brinley Ross, B.Sc., Research Student, University College of North Wales, Bangor.

Williams, Robert Abwyn, B.Sc., Assistant Technical Officer, Imperial Chemical Industries Ltd., Witton, Birmingham.

Williams, Trevor Frank, B.Sc., Health Physicist, U.K. Atomic Energy Authority, Dounreay, Thurso, Caithness.

Fourteen Students and four Subscribers were also admitted.

The Graduateship Examination 1959

The Institute's Graduateship Examination was held on June 1–5. Written papers were taken at centres in Birmingham, London, Paisley, Salford, Sunderland and Swansea ; the practical examination was held in London. In addition one candidate sat for the examination in Melbourne and one in Toronto.

One hundred and nineteen candidates, including seven taking the examination in parts, took papers other than the General paper. Details of the thirty-nine who were successful in all the papers they were required to take to comply with the academic requirements are given below with the name of the college at which they studied in brackets.

Atherton, Brian Godfrey—Worcester Park, Surrey
(*Guildford County Technical College*)
Berger, Ernest John—Thornton Heath, Surrey
(*South East London Technical College*)
Bett, Norman—Cambridge
(*Glasgow University*)
Bevan, Hugh—Pontypool, Mons.
(*University College of Swansea and Monmouthshire College of Technology*)
Boyer, Roy—Manchester
(*Royal Technical College, Salford*)
Burn, Neil—Hadfield, Manchester
(*Royal Technical College, Salford*)
Byrnes, Richard John—London
(*South East London Technical College*)
Charles, Desmond—Smethwick, Staffs.
(*College of Technology, Birmingham*)
Cropper, Frank Brian—Manchester
(*Royal Technical College, Salford*)
Elliott, Michael John Way—Didcot, Berks.
(*Oxford College of Technology*)
Fleming, Peter—Salisbury, Wilts.
(*Bournemouth Municipal College* and *Northampton College of Advanced Technology*)
Hawkes, Geoffrey Allan—Melbourne, Australia
(*Luton and South Bedfordshire College of Further Education* and *Acton Technical College*)
Herbert, Harold—Camberley, Surrey
(*Guildford County Technical College*)
Hunt, Leslie Brian—Port Talbot, Glam.
(*Swansea Technical College*)
Hutchings, John Brian—Sharmbrook, Bedford
(*North Hertfordshire Technical College*)
Irving, William Robert—Teddington, Middx.
(*Guildford County Technical College*)
Livingston, Leslie David—Ellesmere Port, Cheshire
(*Liverpool College of Technology*)
Lucy, George Thomas—Reading, Berks.
(*Reading Technical College*)
Mason, David Bernard—Chingford, London
(*Northampton College of Advanced Technology*)
McCarthy, Brian Dennis—Catford, London
(*South East London Technical College*)
McClure, Richard John—Toronto, Canada
(*South East London Technical College*)
Moore, John Keith—Farnborough, Hants.
(*Guildford County Technical College*)
Norman, Shirley—Manchester
(*Royal Technical College, Salford*)
Parry, Norman Courtenay Jordan—Sevenoaks, Kent
(*South East London Technical College*)
Perry, Donald Garth—Whitton, Middx.
(*University of Leicester*)
Ralf, Geoffrey James—Reading, Berks.
(*Reading Technical College*)
Richardson, Brian Arthur—Camberley, Surrey
(*Guildford County Technical College*)
Richardson, Brian Hall—Wootton Warren, Warwicks.
(*College of Technology, Birmingham*)
Rixon, James—Warrington, Lancs.
(*Royal Technical College, Salford*)
Roskilly, Ian Graham—Sevenoaks, Kent
(*South East London Technical College*)
Scriven, Alan—Bishopton, Renfrewshire
(*College of Technology, Birmingham* and *Battersea College of Technology*)
Shields, Eric—Spennymoor, Co. Durham
(*Sunderland Technical College*)
Smith, John Edwin—Birmingham
(*College of Technology, Birmingham*)
Sparrow, David Beecher—West Bridgford, Nottingham
(*University of Nottingham* and *Nottingham Technical College*) ; also private study
Taylor, Ronald Kenneth—Reading, Berks.
(*Reading Technical College*)
Turner, Alan Edgar—Altrincham, Cheshire
(*University of Liverpool* and *Royal Technical College, Salford*)
Wells, Colin Richard—Greenford, Middx.
(*South West Essex Technical College*)
Whitten, Edward William—Ash, Surrey
(*Guildford County Technical College*)
Wrigley, Robert—Preston, Lancs.
(*Harris College of Further Education, Preston*)

Five candidates took only the Mathematics papers this year and one satisfied the examiner. Two candidates took only the Physics papers this year ; neither was successful. There were twenty-two candidates for the General paper, seven of whom were taking this paper only ; there was a total of four passes of whom one was taking only this paper this year. Two candidates passed the necessary papers in physics but failed the General paper, which they will be required to repeat.

The candidates entered for Applied Heat withdrew before the examination but this paper is reproduced with the other question papers on pp. 229-253.

Table I shows the qualifications held by the 1959 candidates ; the same information is given in Table 2 for all the candidates in the years 1952-59.

TABLE I

Number of candidates and passes for the year 1959 :—

	No. of candidates	*No. of passes*
Holders of degrees	29	13
Holders of the Higher National Certificate in Applied Physics	75	26
Others	8	0
	112	39

TABLE II

Totals of candidates and passes for the years 1952-1959 :—

	No. of candidates	*No. of passes*
Holders of degrees	146	55
Holders of the Higher National Certificate in Applied Physics	274	74
Others	46	7
Total	466	136

TABLE III

1959 EXAMINATION

	No. of candidates	*No. of passes*
Physics I	83	57
Physics II	79	33
Physics III	11	6
Mathematics I	17	2
Mathematics II	17	2
More Advanced Physics	30	21
Applied Optics	1	0
Electronics	27	10
Mathematical Physics	3	0
Nuclear Instrumentation and Measurements	5	4
Spectroscopy	1	0
Statistics	3	1
X-Rays	5	2
Practical Physics	19	18
General Paper	22	4

Papers set in the Graduateship Examination 1959

PHYSICS I—GENERAL PHYSICS AND ACOUSTICS

Examiner : PROFESSOR J. D. CRAGGS, M.SC., PH.D., F.INST.P.

MONDAY, 1st June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. Give three methods for the measurement of the surface tension of soap solution. Discuss one of these methods in detail and comment on the relative accuracy of all the methods mentioned.

2. Describe how to determine the mean density of the earth by two variations of a pendulum method.

3. Describe and explain the mechanism of operation of diffusion pumps for high vacua, and proceed to discuss the general design problems of a dynamic vacuum system.

4. Explain the Doppler effect and give detailed accounts of its importance in various fields of experimental physics.

5. Write an essay on friction.

6. Discuss the significance of Poisson's ratio and show how this quantity may be determined for certain materials by an extensometer method. Show briefly how an optical system may be used for the same purpose.

7. Give a full account of Rayleigh's disc, and its applications.

8. Discuss as fully as possible the acoustical problems involved in the design of a concert hall.

PHYSICS II — HEAT AND OPTICS

Examiner :

PROFESSOR H. LIPSON, M.A., D.SC., F.INST.P., F.R.S.

MONDAY, 1st June—2.00 p.m.

(*Answer* FIVE *questions, at least* TWO *from each section*)

SECTION A

1. Explain what is meant by the equation of state of a substance.

If the equation of state of a substance is

$$\frac{T}{p} = a_0 + a_1 v + \frac{a_2}{T} v^2 + \frac{a_3}{T} v^3,$$

the a's being constants and the other symbols having their usual meanings, deduce what you can about the constants a if the following conditions have to be satisfied :—

(*a*) the substance is a perfect gas at high temperatures,

(*b*) it has a limiting volume b at low temperatures, and

(*c*) its critical temperature is $T_c{}^\circ K$.

2. What is meant by the internal energy of a gas ? Explain how the porous-plug experiment gives information about the internal energy of a gas as a function of pressure, distinguishing clearly between the temperature difference so produced and that produced by adiabatic expansion. Discuss the application of the experiment to the liquefaction of oxygen and hydrogen.

3. Water at 5°C enters a lead tube of internal diameter 4 cm and external diameter 5 cm. If a length of 100 cm is exposed to an external temperature of -5°C, what rate of flow, in cm^3 per sec., will be sufficient to prevent freezing ? Explain any approximations that you find it necessary to make.

If freezing does start, will it continue if the rate of flow is kept constant ?

(Thermal conductivity of lead $= 0{\cdot}083$ cal. cm^{-1}. sec^{-1}. $^\circ\text{C}^{-1}$.)

4. Discuss the concept of free energy in thermodynamics, and explain its use in studying the equilibrium of two phases of a given substance. By considering free energy, or otherwise, show that, in a phase change involving a volume change,

$$\frac{dp}{dT} = \frac{L}{T(v_2 - v_1)}$$

the symbols having their usual meanings.

5. What is Stefan's law ? How would you measure Stefan's constant experimentally ? How would you use the result to measure the temperature of the surface of the sun ?

SECTION B

6. Explain the principles involved in the operation of the fluorescent lamp. Derive an expression for the intensity of illumination at any point near a fluorescent lamp treated as a uniform linear source of light. Show that, on a line bisecting the lamp perpendicularly, the intensity obeys an inverse-square law at large distances and a simple inverse law at small distances.

7. Describe the origin and nature of (*a*) spherical aberration, (*b*) coma. Explain, with the relevant theory, the various ways of eliminating spherical aberration in astronomical objectives.

8. Give a brief account of the behaviour of light on passing through a biaxial crystal. Explain fully any technical terms you use.

A biaxial crystal is placed between crossed polarizers. Explain the phenomena observed when the crystal is rotated about the axis of the polarizers, and show that the phase of the transmitted light changes by π when the crystal passes through an extinction direction.

9. Write a brief essay upon the measurement of the velocity of electromagnetic radiation, concentrating mainly on the most recent determinations. Include also the impact that the measurements have had upon the development of physical theory.

PHYSICS III—ELECTRICITY AND MAGNETISM

Examiner : PROFESSOR J. D. CRAGGS, M.SC., PH.D., F.INST.P.

THURSDAY, 4th June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. Give a full discussion of the ionization and de-ionization mechanisms operative in the discharge column of an atmospheric pressure arc.

2. Describe, with appropriate theory, how to measure the electrical power factor of condensers for high and low frequencies.

3. Derive an expression for the electrostatic potential at a given distance from a point charge in air, and thus determine the capacitance of a condenser with concentric spherical electrodes. Find consequently the capacitance of a parallel-plate condenser with air dielectric.

4. Give an account of thermionic valve circuits for the measurement of very low currents and give examples of applications.

5. Derive an expression for the force on a weakly magnetic body in a non-uniform magnetic field and thus show (Curie's method) how the susceptibility of such a body may be found.

6. Give full details of bridge methods for the measurement of (*a*) high voltages and (*b*) very low currents.

7. Write an essay on nuclear fission.

8. Give the theory and the important constructional details of a Grassot fluxmeter and briefly discuss typical applications of this instrument. Describe another method for the measurement of non-uniform magnetic fields.

MATHEMATICS I

Examiner :

A. W. GILLIES, B.SC., PH.D., F.INST.P.

WEDNESDAY, 3rd June—9.30 a.m.

(*Answer* SIX *questions*)

1. (i) Express as ratios of determinants the solution of the simultaneous equations

$$\begin{aligned} 2x - 2y - 3z &= 7 \\ 3x + 2y - 4z &= -4 \\ x - 3y + 2z &= 13 \end{aligned}$$

and show that $x = 2$.

(ii) Express

$$\begin{vmatrix} 1 & a & a^3 \\ 1 & b & b^3 \\ 1 & 1 & 1 \end{vmatrix}$$

as a product of first degree factors.

2. (i) If $f(x)$ is a differentiable function of x show that $f(a)$ is a minimum value of $f(x)$ if $f'(x)$ changes from $-$ to $+$ as x increases through the value a.

The velocity v of water waves of length λ is given by

$$v = k\sqrt{\left(\frac{a}{\lambda} + \frac{\lambda}{a}\right)}$$

where a and k are constants. Determine the minimum velocity.

(ii) Obtain a set of values for a, b, and c for which $z = ax^2 + bxy + cy^2$ has a minimum value at the origin both for variation of x only and of y only, but for which z does not have a minimum value at the origin when x and y are varied together.

3. A function x of the independent variable t satisfies the differential equation

$$\frac{d^2x}{dt^2} + 2a\frac{dx}{dt} + (a^2 + \omega^2)x = F$$

Discuss the meanings of the symbols in a physical situation which could give rise to this equation.

If x and dx/dt are both zero at $t = 0$ show that

$$x = \frac{F}{a^2 + \omega^2}\left[1 - e^{-at}(\cos\omega t + \frac{a}{\omega}\sin\omega t)\right]$$

and obtain the greatest value of x after $t = 0$.

4. If the function $f(t)$ can be expanded in a series of the form

$$f(t) = \sum_{n=-\infty}^{+\infty} A_n e^{ni\omega t}$$

explain how the coefficients A_n may be determined.

A condenser is charged by a battery of constant e.m.f. E through a resistance so that the potential v across the condenser plates grows according to the law

$$v = E(1 - e^{-t}).$$

When this potential reaches $\frac{1}{2}E$ the condenser is instantaneously discharged, and immediately commences to recharge according to the same law, this cycle being repeated. Determine the period of the cycle and show that the amplitude of the fundamental component of the oscillating potential is approximately $0{\cdot}158E$.

5. Show that the equations

$$x^2 + y^2 + z^2 - 2x + 2y - 23 = 0$$
$$2x + 2y - z = 9$$

represent a circle and find its centre and radius.

6. If $f(x) = \int_x^\infty e^{-t} \frac{dt}{t}$ with x positive, use the substitution $t = x + u$ to transform the integral to one with respect to u. Hence use the identity

$$\frac{1}{1 + \frac{u}{x}} = 1 - \frac{u}{x + u}$$

to show that when x is large $f(x) \simeq e^{-x}/x$ with a fractional error less than $1/x$.

7. A rigid body rotates with angular speed ω about an axis through O in the direction of the unit vector $\hat{\mathbf{a}}$. Show that the velocity $\mathbf{v}$ of the point with position vector $\mathbf{r}$ will be given by

$$\mathbf{v} = \mathbf{A} \times \mathbf{r}$$

$\mathbf{A}$ being the vector $\omega\hat{\mathbf{a}}$. Show also that the speed v may be expressed by

$$v^2 = \mathbf{A}^2\mathbf{r}^2 - (\mathbf{A}.\,\mathbf{r})^2$$

and obtain an expression for the kinetic energy in terms of the components of $\mathbf{A}$ and the moments and products of inertia with respect to cartesian axes with origin at O.

8. Show that the polar equation of an ellipse, with the pole at a focus, may be expressed in the form

$$r(1 + \varepsilon \cos \theta) = p$$

A particle moves round this ellipse with angular speed satisfying $d\theta/dt = h/r^2$ where h is a constant. Show that the speed v satisfies

$$v^2 = \frac{2h^2}{rp} - \frac{(1 - \varepsilon^2)h^2}{p^2}$$

9. A simple periodic function u of the time t is defined by $u = \text{Re}\,(1 + \sqrt{3}i)e^{i\omega t}$. Determine the amplitude, period, and initial phase of u. If $v = \text{Re}(\sqrt{3} + i)e^{i\omega t}$ determine the phase difference between u and v stating which leads.

Obtain also the amplitude and initial phase of $u + v$, and the amplitude of the periodic component of uv.

10. With the usual notation derive the equations $s = c \sinh (x/c)$ and $y = c \cosh (x/c)$ for the common catenary.

A cable is suspended between two points on the same level and 100 ft. apart. If the central sag is 6 ft. show that the length of the cable is slightly less than 101 ft.

MATHEMATICS II

Examiner :

A. W. Gillies, B.Sc., Ph.D., F.Inst.P.

WEDNESDAY, 3rd June—2.00 p.m.

(*Answer* six *questions*)

1. Show graphically that the equation $\tan x = 2x$ has an infinite number of solutions and that these have absolute values slightly less than the odd multiples of $\frac{\pi}{2}$. Determine graphically or otherwise the smallest positive root to three decimal places.

2. (i) Show that $\displaystyle\int_0^1 \frac{(2-2x)dx}{(x+1)^2(x^2+1)} = 1 + \tfrac{1}{2}\log 2 - \frac{\pi}{4}$.

(ii) Show that $3\sin y dx + 2x\cos y dy$ becomes a perfect differential of a function $\varphi(x, y)$ after multiplication by a suitable power of x, and obtain the function $\varphi(x, y)$.

3. A particle of mass M is free to move along an x-axis. It is at rest at the origin at $t = 0$ when a force $MF\sin\omega t$ begins to act on it. Show that although the force oscillates about the mean value zero, the particle moves continuously in the positive x-direction when F is positive. Discuss this result and show that if damping is present producing a resistance Mhv when the speed is v, this steady motion is destroyed and the particle ultimately oscillates about a displaced mean position $x = F/(\omega h)$.

4. The function u satisfies the equation

$$x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = nu$$

Change the independent variables from (x, y) to (ξ, η) where $\xi = y/x$, $\eta = x$ and show that the equation becomes

$$\eta\frac{\partial u}{\partial \eta} = nu$$

Hence deduce that u must be of the form $u = x^n f(y/x)$.

5. P, A, B are points on the complex plane representing z, $+1$, -1 respectively. If $(z-1)/(z+1) = re^{i\theta}$ show how r and θ may be represented geometrically. What is the locus of P if (i) r is constant, (ii) θ is constant ? If Q represents another number w where

$$\frac{w-1}{w+1} = \frac{1}{2}\cdot\frac{z-1}{z+1}$$

show how the loci (i) and (ii) may be used to locate Q.

6. If $\displaystyle f(x) = \int_0^x w(\xi)\,\frac{(x-\xi)^n}{n!}\,d\xi$

prove that

$$f'(x) = \int_0^x w(\xi)\,\frac{(x-\xi)^{n-1}}{(n-1)!}\,d\xi$$

and

$$\int_0^x f(t)dt = \int_0^x w(\xi)\,\frac{(x-\xi)^{n+1}}{(n+1)!}\,d\xi$$

$w(\xi)$ being any integrable function of ξ, and n a positive integer.

7. A uniform rod AB of mass M and length $2a$ is held at rest with the end A resting on a smooth horizontal table. If the rod is released when it is inclined at an angle α to the vertical, describe the subsequent motion and show that when the rod is inclined at θ to the vertical its angular speed is given by

$$\dot{\theta}^2 = \frac{6g(\cos\alpha - \cos\theta)}{a(3\sin^2\theta + 1)}.$$

8. A particle of mass M starting from rest moves along the x-axis under the action of a constant force F and a resistance the value of which is kv^2 when the speed is v. Write down the equation of motion of the particle, show that its speed approaches a limiting value, and that it will reach half this value in a distance

$$\frac{M}{2k}\log_e\frac{4}{3}$$

9. A circle of radius a rolls without slipping on the inside of a circle of radius $2a$. Show that the path described by a point carried by the moving circle is in general an ellipse. For what positions of this point will the path reduce to (i) a circle, (ii) a segment of a straight line.

10. A lamina in the xy-plane has moments of inertia A, B about the x and y axes and product moment F with respect to these axes. Obtain an expression for the product moment with respect to axes through O at angles θ and $\theta + \frac{\pi}{2}$ to Ox. Show that in general there is only one pair of perpendicular lines through O for which the product moment vanishes. What exception is there ?

Find the directions of the principal axes through O of a uniform rectangle $O\,P\,Q\,R$ where P, Q, R are (2, 0), (2, 1), (0, 1) respectively.

MORE ADVANCED PHYSICS

Examiner : PROFESSOR H. LIPSON, M.A., D.Sc., F.INST.P., F.R.S.

TUESDAY, 2nd June—9.30 a.m. to 12.30 p.m.

(*Answer* FOUR *questions*)

1. Discuss the differences between two-dimensional and three-dimensional diffraction. Explain how these differences affect the design of apparatus for the photographic recording of the X-ray diffraction patterns of crystals.

X-rays of wavelength 1·5Å fall on a cubic crystal of cell dimension 6·0Å. What is the smallest angular difference between the settings of the crystal at which it produces the 200 and 220 reflexions ?

2. Explain why multiple-beam interference fringes are much sharper than those produced by two beams.

Give a description of a method whereby the multiple interference is produced by multiple reflexion, and give the theory showing how the profile of the fringes depends upon the coefficient of reflexion. Explain briefly how the method can be adapted to the examination of the surface details of a specimen such as mica.

3. What are the basic principles of operation of (*a*) the cyclotron, (*b*) the synchrotron, (*c*) the synchrocyclotron, and (*d*) the linear accelerator? Discuss the relationships between these machines and explain the circumstances under which each is used.

4. In what ways can a body be caused to emit electrons ? Describe the apparatus necessary for the investigation of *one* of the phenomena described and give a brief indication of the theory underlying it. Describe briefly the field-emission microscope and mention some of the results obtained with it.

5. Give an account of the modern theory of electrical conduction in metals and explain how it is modified to include semiconductors. Give the basic theory of the transistor and discuss its advantages and disadvantages compared with the vacuum valve.

6. What is the mechanism of production of continuous radiation from an X-ray tube ? Account for the short wavelength limit that is found.

Describe how you would determine a quantitative relationship between the fundamental constants by measuring this limit, emphasizing the precautions you would take to derive as precise a result as possible.

7. Describe the Michelson-Morley experiment for determining the variation of the velocity of light with direction in space, and explain why it is said to be one of the crucial experiments in physics.

APPLIED OPTICS

Examiner :

C. A. TAYLOR, B.SC., PH.D., F.INST.P.

TUESDAY, 2nd June—2 p.m. to 5 p.m.

(*Answer question 1 and* FOUR *other questions; question 1 must be attempeed*)

1. Explain the basic principle of the telephoto lens. A simple telephoto combination consists of a thin converging lens of focal length 5 cms and a thin diverging lens of focal length 3 cms which may be placed either 2·5 or 3·0 cms apart. Determine, either graphically or otherwise, the cardinal points of the system for both separations and discuss their relative merits as telephoto systems.

2. Write an essay on polarized light and its application to the study of strains in transparent materials.

3. Describe the Michelson interferometer and explain how it should be adjusted to obtain (*a*) straight fringes with monochromatic light, (*b*) circular fringes with monochromatic light, and (*c*) fringes with white light.

Various modifications of the Michelson interferometer for testing optical components are known; describe any one with which you are familiar.

4. Discuss the main factors to be considered in the design of a spectrophotometer for the visible region of the spectrum. What are the essential differences between this instrument and one designed (*a*) for the ultra-violet region and (*b*) for the infra-red region ?

Give a detailed description of the optical system of ONE spectrophotometer (visible, ultra-violet *or* infra-red).

5. A simple astronomical camera consists of a plate holder at one end of a tube and a single-component converging lens at the other. Discuss all the factors (optical and photographic) which might be expected to influence the resolution if it were used to photograph double stars. What advantages would be gained by increasing the diameter of the lens (and, of course, the tube) without changing its focal length or other characteristics ?

6. Explain why most optical instruments are fitted with eyepieces comprising two or more lenses rather than with single lenses. Discuss the factors to be considered in designing an eyepiece and give full details of TWO different types of eyepiece. Describe the special features of each and, in particular, explain the advantage of each over a single lens.

7. You are asked to compare the sensitivities of two different photographic emulsions for a number of different wavelengths in the visible region. Describe carefully the apparatus you would set up, and the measurements you would make. What would be the main difficulties you would expect to encounter ?

8. A transmission grating has 4500 lines in a total width of 4 cms and parallel light falls normally on to it. Calculate (*a*) the angle at which the first order maximum for a wavelength of 5900Å would occur, (*b*) the angle at which the second order maximum for a wavelength of 6500Å would occur and (*c*) the resolving power for both first and second order spectra. Derive any formulæ required.

What would be the effect on each of these calculations if the grating were masked so that only a width of 1 cm was allowed to transmit light, the other conditions being unchanged ?

9. Two partially silvered glass plates are separated by a small air space and are accurately parallel to each other. A parallel beam of white light passes normally through the plates and is then brought to a focus on the slit of a spectrometer. Bright bands are seen corresponding to wavelengths 5000Å and 6000Å and there are nine other bright bands between these two. What is the separation of the plates ? If the air space is then filled with a liquid of refractive index 1·34, what would be the wavelength corresponding to the bright band nearest to 5000Å ?

APPLIED HEAT

Examiners :
A. E. De Barr, B.Sc., F.Inst.P., and W. H. Rees, M.Sc., F.Inst.P.

TUESDAY, 2nd June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions*)

(*The required numerical data are given at the end of the paper*)

1. Describe a method of determining the thermal conductivity of glass wool. Consider particularly the errors to which the method may be subject, and list the factors that must be taken into account in expressing the result of the measurement.

A heated cylindrical bar of thermal conductivity 25 B.Th.U./hour ft^2(°F/ft) is covered with a shell of concrete of thermal conductivity 0·5 B.Th.U./hour ft^2(°F/ft). The coefficient of heat transfer from the surface of the assembly to the ambient air is 2·0 B.Th.U./hour ft^2(°F). Calculate the radius of the assembly for which the rate of heat loss is a maximum.

Comment briefly on the effectiveness of pipes housed in concrete ceilings or floors for heating a room.

2. (i) The surface coefficient of heat transfer between the inner surface of a cylindrical tube and a fluid in streamline flow through the tube depends upon the following variables :—the diameter and ratio of length to diameter of the tube : the velocity, thermal conductivity and thermal diffusivity of the fluid. Derive a dimensionless equation for the heat transfer coefficient under these conditions.

How many experiments would be needed to express the heat transfer coefficient numerically in terms of the quantities listed above ?

(ii) Define and discuss briefly the practical significance of the following dimensionless numbers : Reynolds' number, Prandtl number, Nusselt number.

3. Explain in words why the presence of a thin screen, both sides of which are of emissivity 1, surrounding a hot body maintained at a given temperature reduces the rate of heat loss by radiation from the body. How would the effectiveness of the screen be altered if its emissivity was 0·1 ?

Two large parallel plane surfaces, 8 mm apart, are maintained in air at temperatures of 30°C and 20°C respectively. Assuming that heat transfer by convection can be neglected, calculate the total heat transfer across the gap under the following conditions :

(i) if each surface is painted with lacquer ($\varepsilon_1 = \varepsilon_2 = 0{\cdot}95$)
(ii) if one surface is painted with lacquer and the other with aluminium paint ($\varepsilon_1 = 0{\cdot}95$: $\varepsilon_2 = 0{\cdot}5$)
(iii) if each surface is of polished metal ($\varepsilon_1 = \varepsilon_2 = 0{\cdot}05$)
(iv) if the gap between the surfaces is filled with an opaque insulating material of thermal conductivity $4{\cdot}5.10^{-4}$ watt/cm^2 (°C/cm).

Discuss the relative effectiveness of the four insulating systems considered.

Thermal conductivity of air at N.T.P. ... $2{\cdot}5 \cdot 10^{-4}$ watt/cm^2 (°C/cm)

4. Derive the thermodynamic relation between the latent heat of evaporation and the rate of change of saturation vapour pressure with temperature. Explain the practical significance of this relation.

How is the heat transfer from a condensing vapour to a surface affected by the mode of condensation, and how may the mode of condensation be influenced ?

If the rate of change of the saturation vapour pressure of water with temperature at 100°C is 27·12 mm of mercury per °C, calculate the specific volume of saturated water vapour at 100°C.

5. Discuss the mechanism of combustion reactions, with particular reference to flame propagation.

What is meant by the " limit of inflammability " and upon what factors does it depend ? How may the limit of inflammability be determined ?

6. Write a short essay on refrigeration, including a reference to the potentialities of semiconductor thermoelements for this purpose.

A perfect heat engine is to be used to make ice at 0°C from water at 20°C using brine at − 12°C. How many kilograms of ice will be made per indicated kilowatt hour ?

7. Write an account of the requirements of materials for high, moderate and low temperature thermal insulation, and indicate how far these requirements are met by commercially available materials.

Discuss the factors that can affect the thermal transmission properties of insulating materials.

8. Explain the physical principles underlying the operation of industrial recording instruments for monitoring the amount of (i) carbon dioxide, (ii) carbon monoxide, (iii) oxygen in flue gases.

Flue gas from a furnace burning coal contains 11% CO_2, 1% CO and 6·7% O_2. The coal contains 74% carbon, 8% ash and negligible nitrogen and sulphur. Calculate (i) the composition of the coal, as percentages of carbon, net hydrogen, water and ash, (ii) the percentage excess air.

9. Give a block diagram of a closed-loop control system. Explain the function of each component with reference to a description of an electrical or pneumatic system for proportional control of temperature in a boiler.

Water, initially at a temperature of T_1, flows through a vat, of capacity C, of perfectly mixed liquid in which the temperature is T_2, the outflowing water being also at T_2. Assuming that no heat is lost to the surroundings and that the thermal capacity of the vat itself is negligible, set up a dynamic heat balance for the system and hence derive the response time or lag.

Numerical Data

Stefan-Boltzmann constant	$5{\cdot}72 \,.\, 10^{-12}$ watt cm^{-2} $(°K)^{-4}$
Mechanical equivalent of heat, J	$4{\cdot}18 \,.\, 10^{7}$ erg.cal^{-1}
Composition of air	20·9% O_2 79·1% N_2
Latent heat of fusion of ice at 0°C	80 cal g^{-1}
Latent heat of vaporization of water at 100°C	540 cal g^{-1}

ELECTRONICS

Examiner :
A. E. De Barr, B.Sc., F.Inst.P.

TUESDAY, 2nd June—2.00 p.m.

(*Answer question 1 and* FOUR *other questions; question 1 must be attempted*)

(*The required numerical data are given at the end of the paper*)

1. (*a*) A two-stage amplifier, having negligible phase-shift and a voltage amplification of 10,000 without feedback, has 1/1000 of its output fed back in anti-phase to its input. Determine the change in amplification that will result from a reduction of 20% in the mutual conductance of the valves employed.

(*b*) A parallel-tuned circuit consisting of a lossless inductance of 7·5 mH, a resistor of 220 kΩ and a capacitor, is resonant at 150 kc/s. Calculate the value of the capacitance and the bandwidth of the circuit.

(*c*) Calculate the voltage sensitivity of a cathode-ray tube having an accelerating voltage of 2,000 volts and parallel-plane deflector plates 3 cm long and 1 cm apart, the mid-point of the plates being 35 cm from the screen.

(*d*) Show that, for an unsmoothed half-wave rectifier, the efficiency of rectification cannot exceed 40·6%.

2. In a metal in thermal equilibrium the number of electrons per unit volume with energies between E and $E + \delta E$ is proportional to

$$\frac{E^{\frac{1}{2}}\delta E}{\exp\dfrac{(E - E_F)}{kT} + 1}$$

Sketch the shape of the curves showing the distribution of electron energies at absolute zero and at room temperature, and explain the significance of E_F.

For tungsten $E_F = 5{\cdot}8$ eV. Explain carefully why those electrons with energies of about E_F do not leave the metal.

What properties of a material determine its usefulness as a cathode surface for thermionic valves ?

3. What is meant by space charge? Explain how it is formed. Write down the equation of motion for an electron in a diode valve, taking account of space charge, and hence explain the effect of space charge in (i) a vacuum diode, (ii) a gas-filled diode.

Explain briefly the action of a crystal diode and discuss the relative merits of crystal and vacuum diodes as rectifying devices.

4. Use the band theory of solids to explain the mode of action of (i) photovoltaic, (ii) photoconductive, and (iii) photoemissive cells.

Describe briefly typical applications of each type of cell, and explain why one type of cell is more suitable than the others for each application.

Determine the value of the threshold wavelength, the maximum velocity of the electrons emitted, and the quantum yield efficiency for a cathode material having a work function of 1·9 eV, and a sensitivity of 18μA/lumen when light of wavelength 5893Å (luminous efficiency 620 lumen/watt) is incident upon it.

5. Distinguish between regenerative, relaxation and negative resistance oscillators, giving one example of each. Compare the suitability of these types of oscillator for different applications.

Describe one other type of oscillator and explain what determines its frequency of oscillation.

In a 5 kc/s simple relaxation oscillator the condenser has a value of 0·1μF, the striking voltage of the discharge tube is 100 volts and the extinction voltage is 20 volts. If a 500 volt supply is used, what value of charging resistor will be required ? (The discharge time may be neglected).

6. Explain the causes of, and ways of minimizing, the following effects in high gain amplifiers : (i) microphony, (ii) valve noise, (iii) Johnson noise, (iv) hum, (v) unwanted coupling between stages. What is the relation between gain and band-width in an amplifier ?

7. Explain, with reference to a single-valve amplifier with a resistive load and a cathode resistor without a bypass condenser, what is meant by the output and input impedances of a device. Show how these quantities can be calculated for any network.

What is their significance and importance ?

Draw the equivalent circuit of a cathode follower, including all inter-electrode capacitances, and use this to derive an expression for the input capacitance of the circuit. What would be the input capacitance of a conventional amplifier of the same gain ?

8. What are the essential requirements for a power amplifier to operate under Class A conditions ? Explain the advantages and disadvantages of this mode of operation.

Explain the factors that have to be considered in designing an output stage for a high-fidelity audio amplifier intended to deliver 10 watts to a moving-coil loudspeaker.

A triode valve arranged as a Class A audio-frequency amplifier drives a 10 ohm loudspeaker. The optimum anode load is 3800Ω. The quiescent current is 60 mA with a grid bias of -40 volt. When the peak input signal is applied the anode current swings up to 120 mA and down to 10mA. The anode supply voltage is 460 volts and under peak signal conditions the anode voltage swings up to 650 volts and down to 120 volts. Calculate suitable values for the output transformer ratio and cathode bias components. Calculate also the power output at fundamental frequency, the efficiency and the percentage of second harmonic in the output.

9. Write an account of the conduction of electricity in gases with special reference to (i) a thyratron, (ii) a Geiger-Müller counter, (iii) a multi-cathode ring counting tube (Dekatron).

Describe and explain, with circuit diagrams, one application of each of the above devices, and in each case mention an alternative way of performing the same operation.

Numerical Data

Electronic charge, *e*	$1{\cdot}602.\ 10^{-19}$ coulomb
Electronic mass, *m*	$9{\cdot}107.\ 10^{-28}$ g
Planck's constant, *h*	$6{\cdot}624.\ 10^{-34}$ joule. sec

MATHEMATICAL PHYSICS

Examiner : A. W. GILLIES, B.SC., PH.D., F.INST.P.

TUESDAY, 2nd June—2 p.m. to 5 p.m.

(*Answer* FOUR *questions*)

1. The displacement x of a simple harmonic oscillator satisfies the equation

$$\frac{d^2x}{dt^2} + \omega_o^2 x = F$$

where F denotes an applied force. For $t \leqslant 0, F=0$ and the oscillator is at rest ; for $t > 0, F = a \cos \omega t$. Show that a beat is obtained between the free and forced oscillations when $|\omega - \omega_o|$ is small but not zero. Examine the behaviour of this solution as $\omega \rightarrow \omega_o$ and deduce the solution for $\omega = \omega_o$ as the limiting form.

2. A body of mass M and centre of mass G is suspended by vertical springs at A and B in line with G and at distances a, b respectively on opposite sides of G. The ratios of tension to change of length for the springs are λ and μ, and in equilibrium AGB is horizontal. Use the method of Lagrange to derive the equations of motion for small displacements from the equilibrium position in which G moves vertically and the body rotates about G through a small angle in the plane of the springs, the moment of inertia being Mk^2. Determine the periods of the normal modes and show that if $a\lambda = \mu b$ there is no coupling between the vertical motion and the rotation.

3. A membrane of mass m per unit area is stretched with uniform tension T. In equilibrium it lies in the xy plane. If it is deformed so that each point (x, y) is displaced perpendicularly to the xy plane by a small amount z show that the portion of the membrane within any closed curve C is subject to the force in the z direction of magnitude

$$T\int_c \left(\frac{\partial z}{\partial x}dy - \frac{\partial z}{\partial y}dx\right)$$

as a result of the tension. Hence or otherwise derive the differential equation for z when no other forces are present. Show that if the membrane is a square of side a clamped so that $z = 0$ on the boundary, the frequency f of the fundamental mode is

$$f = \frac{1}{\sqrt{2}\, a}\sqrt{\frac{T}{m}}$$

4. Derive Poiseuille's law giving the volume Q of liquid of viscosity η flowing per unit time through a horizontal capillary tube of radius a and length l, in the form

$$Q = \frac{\pi a^4 (p_1 - p_2)}{8\eta l}$$

p_1 and p_2 being the pressures at the ends of the capillary. Discuss any assumptions made in the derivation of the law.

5. Describe the method of electrical images for the solution of electrostatic problems. Illustrate your answer by discussing the distribution of charge on a conducting sphere of radius a when a point charge Q is situated at a distance b ($> a$) from its centre. Consider the two cases when the sphere is (a) insulated and (b) earthed.

6. How would you define the mean value of a function $f(x, y, z)$ on a surface S ?

A point charge of magnitude Q is situated at the point $(0, 0, b)$. Calculate the mean value of the potential produced by this charge at points on the surface of the sphere of radius a with centre at the origin, in the two cases $b > a$ and $b < a$.

7. Obtain the conditions which have to be satisfied by the components of an electromagnetic field at the boundary between two media.

Write down the equations of a plane electromagnetic wave travelling in the direction of the positive x-axis in a non-conducting medium, the electric vector being parallel to the y axis. If the yz plane is a boundary between medium 1 and medium 2 and the above wave is incident on this surface, determine the equations of the reflected and refracted waves.

8. A particle of mass m moves along the x-axis. The potential energy is $-U$ for $|x| < a$ and zero for $|x| > a$. Apply the Schrödinger equation to obtain the quantized values of the energy E of the particle when $E < 0$.

9. S, S_1, S_2 are three inertial frames in relative motion in the direction of their x-axes which are parallel. The speed of S_1 relative to S is v_1, and of S_2 relative to S is v_2. Write down the Lorentz transformations connecting measurements in S_1 and S_2 respectively with measurements in S. Obtain from these the transformation connecting S_1 and S_2. If the speeds v_1 and v_2 are both less than c, show that the speed of S_2 relative to S_1 is also necessarily less than c.

NUCLEAR INSTRUMENTATION AND MEASUREMENT

Examiners :

A. E. De Barr, B.Sc., F.Inst.P., and D. Greene, B.Sc., Ph.D., A.Inst.P.

TUESDAY, 2nd June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions*)

(*The required numerical data are given at the end of the paper*)

1. Give examples of nuclear reactions and discuss the energy relations involved.

Calculate the minimum photon energy required for the reaction :

$$C_{12} + \gamma = C_{11} + n$$

Mention a practical application of this result.

2. Explain how the absorption of a neutron beam in a material can be specified by the use of cross-sections. Describe briefly how you would measure these quantities.

Slow neutrons are captured by Co_{59} to give the radioactive isotope Co_{60}. The capture cross-section is $2{\cdot}2 \,.\, 10^{-23}$ cm^2. Calculate the rate of production of Co_{60} nuclei in a 1g sample of metallic cobalt placed in a neutron flux of 10^{10} cm^{-2} sec^{-1}.

3. By varying the voltage applied between a gas-filled cylinder and a coaxial wire within it, the system can be used as an ionization chamber, a proportional counter, or a Geiger counter. Describe the physical principles underlying the operation of these three devices and explain the types of application for which they are suitable.

Calculate the time required for a positive ion to move from the wire to the wall of a Geiger counter. [The diameter of the cathode wall is $1\frac{1}{8}$ inch, the diameter of the wire is 0·005 inch, the voltage applied between wire and cathode is 1000, the gas pressure is 10 cm of mercury, and the mobility of the ion at 1 volt cm^{-1} and a pressure of 76 cm of mercury is 1·5 cm sec^{-1}].

Comment on the significance of this result.

4. Describe the construction, characteristics and applications of scintillation counters.

The counting rates (after correction for background) obtained with a recently irradiated sample are given in the table :

Time, in minutes	0	2	4	6	8	10	12	14
Counts, per minute ...	1100	930	740	605	520	420	360	310

Time, in minutes	16	18	20	22	24	28	30
Counts, per minute ...	275	240	210	180	160	120	105

Interpret these results.

5. The particles emitted by a radioactive material are randomly distributed in time. Discuss the statistical problems arising when the particles are counted.

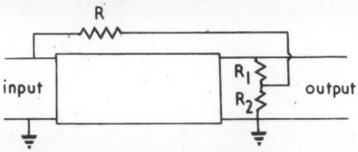
The activities of two sources, A and B, of identical shape and chemical composition, are to be compared. With a particular counting system A gives 5200 counts in 10 minutes, and B gives 3850 counts in the same time. The background counting rate is found to be 920 counts in 15 minutes. Calculate the ratio of the activities of the two sources, and some measure of the possible error involved.

6. Describe the physical principles involved in the operation of an expansion chamber, and explain the types of information that can be obtained with such a chamber.

Compare the properties and applications of cloud and bubble chambers.

7. Discuss the use of negative feedback to improve the performance of d.c. amplifiers.

The " box " in the figure is a high-gain d.c. amplifier. A current of 10^{-8} amp. from an ionization chamber is fed into the input point. The values of the resistors shown are $R = 50\text{M}\Omega$, $R_1 = 20\text{k}\Omega$, $R_2 = 10\text{k}\Omega$. What is the voltage across the output terminals ?



What would be the effect of replacing R by a capacitance ?

8. Describe in detail the construction, operation and applications of TWO of the following circuits : (i) a scale-of-two counter, (ii) a multivibrator, (iii) a coincidence circuit.

9. Write an account of the precautions required in the handling of radioactive materials.

A source contains 100 mg. of radium filtered by 0·5 mm of platinum. What would be the dose rate at 30 cm from the source ? What thickness of lead would be required to reduce the dose rate to 0·3 r day^{-1}?

Numerical Data

Mass of C_{11}	11·0149 mass units
Mass of C_{12}	12·0038 mass units
Mass of neutron	1·0089 mass units
1 mass unit	910 Mev
K factor for radium filtered by 0·5 mm of platinum	8·4 r hour^{-1} at 1 cm.
H.V.L. of lead for radium radiation	6·9 mm.
Avogadro's number, N	6·025 . 10^{23} per g molecule

SPECTROSCOPY

Examiner :

A. E. De Barr, B.Sc., F.Inst.P.

TUESDAY, 2nd June—2.00 p.m.

(*Answer questions 1 and 2 and* THREE *other questions; questions 1 and 2 must be attempted*)

(*The required numerical data are given at the end of the paper*)

1. Write an account of the origin of emission and absorption spectra in terms of the Bohr model of the atom. Explain briefly how this account could be extended to include molecular spectra.

Make an approximate estimate of the effective quantum numbers of the states between which transitions occur to give the sodium D lines, taking the ionization potential of sodium as 5·12 volts and the mean D line wavelength as 5893 Å.

2. State Lambert's and Beer's laws of absorption, and explain how they can be combined to give the Beer-Lambert law. Comment on the validity of this law and discuss the factors limiting its operation.

The optical density (at a wavelength of $7{\cdot}65\mu$ and a cell-length of 9·5 cm) at 20°C of a mixture of methane with oxygen at a constant total pressure of 80 cm of mercury is given as a function of the partial pressure of methane in the table below :—

Partial pressure of methane (cm Hg) :	2·5	5·0	10·0	20·0
Optical density :	0·2	0·25	0·35	0·45

Estimate the molecular extinction coefficient for methane at this wavelength, and suggest possible reasons why the optical density does not vary linearly with the partial pressure at the higher pressures.

3. Derive an expression for the resolving power of a prism. What effect do the other components of a prism spectrograph have upon the resolving power of the instrument ?

Explain the construction of prism and grating spectrographs for use in the near ultra-violet region, and comment on the advantages and disadvantages of each type of instrument.

4. What factors determine (i) the choice of a method of excitation of line spectra, (ii) the lines chosen for measurement, when a spectrograph is used for quantitative analysis ?

Describe the use of internal standards and compare this method with alternative methods of calibration.

5. Describe the type of equipment you would install, and the procedure you would adopt, if you were asked to set up spectrographic equipment for routine analysis in EITHER (*a*) an oil refinery, or (*b*) a hospital.

Indicate the sort of problems that might arise and the way in which you would tackle them.

6. Discuss the properties of the sources and detectors at present available for use in infra-red spectroscopy, and show how these influence the design of infra-red spectrometers. What factors limit the sensitivity of the detectors at present available, and what are the prospects of obtaining detectors of increased sensitivity ?

Sketch the design of a double-beam infra-red spectrometer, giving dimensions for essential parts and indicating the materials used.

7. Explain briefly the chemical effects of (*a*) exposing, (*b*) developing, and (*c*) fixing a photographic plate. Explain the nature of the relation between exposure and optical density of a photographic emulsion, and describe how and why it varies with the wavelength of the radiation to which the emulsion is exposed.

Describe some form of microdensitometer suitable for investigating the variation of density across a spectral line on a photographic plate, and comment on the extent to which the result corresponds to the distribution of intensity in the original spectrum.

8. Write notes on (i) the Stark effect, (ii) monochromators, (iii) multi-source units.

9. Discuss the following lens aberrations, explaining carefully under what circumstances they arise and how they may be measured : spherical aberration, chromatic aberration and astigmatism.

To what extent are these aberrations important in a lens forming part of a spectrograph?

Numerical Data

Rydberg constant, R	1·097 . 10^{5}cm^{-1}
Planck's constant, h	6·61 . 10^{-27} erg. sec.
Electronic charge, e	1·602 . 10^{-19} coulomb
Electronic mass, m	9·107 . 10^{-28} g
Velocity of electromagnetic waves in free space, c	3 . 10^{10} cm sec^{-1}

STATISTICS

Examiner :

E. D. van Rest, M.A., B.Sc., F.Inst.P.

TUESDAY, 2nd June—2 p.m. to 5 p.m.

(*Candidates should answer not more than* FOUR *questions including at least* ONE *from the first three*)

1. An abrasion testing machine has four heads (*a*, *b*, *c*, *d*) or positions for attachment of material under test. Four separate runs (*1*, *2*, *3*, *4*) using all four heads are made in order to compare four materials *A*, *B*, *C*, *D*.

In order to remove from the comparison variation which might be supposed to originate with the heads and with the runs, it is arranged that each material shall be tested once on each run and once on each head. The results, identified as to material, head and run by the numbers and letters given above were :—

a1A 140 ; *a4B* 85 ; *a3C* 127 ; *a2D* 128 ; *b4A* 155 ; *b1B* 131 ; *b2C* 165 ; *b3D* 126 ;
c2A 163 ; *c3B* 108 ; *c4C* 118 ; *c1D* 117 ; *d3A* 150 ; *d2B* 119 ; *d1C* 120 ; *d4D* 114

Carry out an analysis of variance ; estimate the residual variance of a comparison between any two materials ; state whether the variability associated with heads is important ; find confidence limits for the worst material (highest average).

2. A grinding operation which is difficult to control is examined by measuring the widths of 500 piston rings produced by the process. The cumulative frequency distribution F = number of rings

having (width in inches − 0·15 inches) less than $x \,.\, 10^{-4}$ is given below.

$x =$	5	7	9	11	13	15	17	19	21	23	25	27	29
$F =$	0	3	5	20	61	134	243	357	428	471	484	496	500

Compare the frequencies in the classes so delimited with those from a normal distribution with the same mean and variance. Make a chi-squared test of significance of the discrepancies. From an examination of your calculations what is it possible to say about the ability of the process to keep below a tolerance limit of $x = 23 \,.\, 10^{-4}$?

3. The tensile strength of cement test pieces is known to increase with curing time according to an exponential law, i.e. that y, the strength, and t the curing time are related by a formula $y = a \exp(-b/t)$.

The following observations of $\log_e y$ were made for several values of t. Estimate the constants a and b and give confidence limits for the ultimate strength.

$1/t =$	*0·5*	*0·2*	*0·10*	*0·08*	*0·05*	*0·04*
	1·315	1·525	1·520	1·500	1·630	1·522
	1·354	1·508	1·583	1·600	1·602	1·590
	1·321	1·473	1·544	1·592	1·514	1·636
	1·373	1·488	1·532	1·546	1·565	1·571
			1·601	1·573	1·587	1·580
					1·540	1·591

It may be assumed that the variance within each of these columns is approximately the same.

4. If x can take values from $-\infty$ to $+\infty$ and is distributed with a probability density function

$$dP(x) = \frac{1}{\sqrt{(2\pi)}} e^{-x^2/2}\, dx$$

what is the probability density function of $z = x^2/2$. ? Find the mean value of z and, using any statistical table available to you, a value which is exceeded by 10% of the values of z.

5. Write briefly about ONE of the following :—

(*a*) Any example of a statistical significance test you know about. Give the background to the problem, the reason for the test, the assumptions made, the hypotheses tested, the test used and the outcome.
(*b*) The statistical aspects of design of experiments.
(*c*) The theory and uses of acceptance sampling schemes.

6. Show that, if f is a function of two independent quantities u and v, and $V(x)$ stands for the variance of x,

$$V(f) = \left(\frac{\partial f}{\partial u}\right)^2 V(u) + \left(\frac{\partial f}{\partial v}\right)^2 V(v)$$

Apply this formula to a density determination effected by weighing and measuring cubes of material. If the coefficient of variation (c.v.) of the weighing procedure is 0·01, what must be the c.v. of length measurement in order to achieve a c.v. of 0·018 in the density determination?

7. A counter is arranged to record the number of occasions during each of 500 short constant time periods that the random noise from an electric circuit exceeds a certain amplitude. The record of counts is :—

c = no. recorded	0	1	2	3	4	5
f = no. of periods recording c.	202	181	83	26	7	1

If these excessive amplitudes are equally likely to occur at any instant what form would you expect the distribution to take, and what variance and third moment about the mean would you expect the number c to have ? Check whether the recorded c's have these values for the moments.

8. A machine produces parts whose lengths are normally distributed about 0·601 inches with a standard deviation of 0·001 inch. What proportion of parts would be expected to be of lengths greater than 0·602 inch and how would this proportion be expected to vary in lots of 100 randomly chosen from the product ? The rule is made that whenever a sample of 100 shows fewer than 10 to be greater than this length a change in the mean for the process will be suspected. How frequently will this occur when in fact there is no change ?

X-RAYS

Examiners :

A. E. DE BARR, B.SC., F.INST.P., and D. GREENE, B.SC., PH.D., A.INST.P.

TUESDAY, 2nd June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions*)

(*The required numerical data are given at the end of the paper*)

1. A narrow beam of X-rays passes through a medium. Describe the processes that occur and discuss the factors that influence the intensity of the emergent beam. How are these processes influenced by (i) the wavelength of the X-rays, (ii) the nature of the medium?

In what way is the situation changed if the X-ray beam is broadened ?

If the Kα and Lα absorption edges of tungsten are 0·1782 Å and 1·022 Å respectively, calculate the wavelength of the Kα radiation of tungsten.

2. Describe the circuit of a constant-voltage X-ray equipment, explaining how the tube current and voltage can be varied and measured. What determines the upper limit of the voltage obtainable from this type of equipment ?

Describe some means of stabilizing the current in an X-ray tube.

3. Define the roentgen and describe the apparatus required to make an absolute measurement of the output of an X-ray tube. Explain the precautions that must be taken in making this measurement.

If the output of a 250 kV X-ray tube is 100 roentgen min^{-1} at the point at which it is to be measured, and an electrometer of input resistance $10^{10}\Omega$ is available, design an ionization chamber which will give an input signal of 1 volt.

4. Explain what is meant by the characteristic curve of an X-ray film and describe in detail how you would obtain this curve for a particular film. How is the shape of the characteristic curve influenced by the quality of the X-rays to which the film is exposed ?

Define the parameters that can be deduced from the characteristic curve to specify the essential properties of the film. Explain how and why the curve is modified by the use of a calcium tungstate screen.

5. Describe the construction and principle of operation of any apparatus for producing X-rays of energy greater than 1 Mev. For what applications is this type of apparatus required ?

The absorption coefficient of steel for the X-rays from such a machine is 0·2 cm^{-1}. If the exposure required for a satisfactory film is about 1 rad, estimate the exposure time for a radiograph of a weld in a 3 inch steel plate at a source-film distance of 2 m, if the output of the machine is 120 rad min^{-1} at 1 m.

6. Describe the effect on an X-ray image of a large focal spot.

A γ-ray source is 0·5 inch in diameter. A specimen 6 inches thick, with holes in its mid-plane, is radiographed at a source-film distance of 36 inches, the specimen being placed immediately in front of the film. Find the minimum spacing between holes that can be distinguished on the film. How could this arrangement be improved ?

Discuss the factors that determine the minimum detectable spacing.

7. Distinguish between X-ray spectroscopy and the use of X-ray powder patterns as methods of chemical analysis. Explain the principles underlying the operation of each method and indicate the types of analysis most suited to it. Give an indication of the sensitivity of each method, and list the factors that influence the sensitivity.

Explain briefly one other method of chemical analysis by means of X-rays, and mention one application of this method.

8. Write an account of the use of X-rays in the measurement of strain and stress, with particular reference to the measurement of the sum of the principal stresses in the plane of a surface. What are the limitations of X-ray methods for such measurements ?

Back-reflection X-ray diffraction photographs are taken with CrKα_1 radiation from a steel specimen before and during a tensile test. The X-ray beam is normal to the film and to the surface of the specimen, and the diameters of the $\{211\}$ rings are :

Before test ...	2·24 cm
During test ...	2·275 cm

Estimate the surface stress in the specimen during the test.

9. Write an account of the precautions that should be taken to protect the users from the radiation from a source of X-rays. Mention briefly the biological reasons for these precautions.

Numerical Data

1 coulomb	$3 . 10^9$ e.s.u
Wavelength of Cr Kα_1 radiation	2·285 Å
Lattice constant of steel (b.c.c.)	2·861 Å
Young's Modulus for steel	$2 . 10^{12}$ dyne cm^{-2}
Poisson's Ratio for steel	0·3

PRACTICAL PHYSICS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P. ; J. Yarwood, M.Sc., F.Inst.P.

FRIDAY, 5th June

(*All day beginning at 9.30 a.m.*)

(Two *questions, selected by the Examiners, will be allotted to each candidate*)

1. Determine the latent heat of vaporization of liquid air.

2. Find the dispersive power of the glass of the given prism.

3. Measure the self-inductance of the coil provided by means of an alternating-current bridge method.

4. With the apparatus provided determine the surface tension of water.

5. By studying the focusing of the electrons in a small cathode-ray tube enclosed within a long solenoid, find the value of the specific electronic charge (e/m).

6. Plot the electrostatic field in the diametral plane between two coaxial cylindrical conductors across which a potential difference is maintained.

7. Determine the refractive index of carbon dioxide gas at room temperature.

8. Using scintillation-counter apparatus investigate as far as you are able the gamma-ray energy spectrum of the radioactive nuclide, caesium 137.

9. Determine the thickness of the given film of mica by means of a Michelson interferometer.

10. Apparatus is provided in which a gas-focused electron beam is produced within a spherical bulb. The bulb is set up within a pair of Helmholtz coils. Verify by experiment the equation relating the radius of curvature of the electron beam to the magnetic field strength and the momentum of the electron.

11. Prepare a thin film of magnesium fluoride on part of a glass plate and measure the transmission for white light of the coated and uncoated parts of the plate.

12. In accordance with the instructions provided prepare a bromine-quenched Geiger-Müller tube and determine its threshold voltage and the slope of the plateau of its characteristic.

13. Calibrate a Pirani gauge against a McLeod gauge over the pressure range from 10^{-2} to 1 mm of mercury.

14. Determine the first excitation potential and the first ionization potential of mercury.

15. Find the wavelength in alcohol of an ultrasonic beam by using an optical diffraction method.

16. With the quartz monochromator investigate the spectrum of a mercury-vapour lamp.

17. Plot the current-voltage characteristic for ionized air within a parallel-plate ionization chamber.

18. Construct a dynatron oscillator and calibrate it against a standard frequency source.

GENERAL PAPER

Examiner : N. CLARKE, B.SC., F.INST.P.

TUESDAY, 2nd June—9.30 a.m. to 12.30 p.m.

(*Answer questions* ONE *and* TWO *and any* THREE *others*)

1. Give the substance of the following passage in your own words:

" In combination with other infernal contraptions, like rockets to deliver bombs at large distances, chemical, biological and radio-active poisons, such a war must mean a degree of human suffering and degradation which is beyond the power of imagination. No country would be immune, but those with highly developed industry would suffer most. It is very doubtful whether our technological civilization would survive such a catastrophe. One may be inclined to regard this as no great loss, but as a just punishment for its shortcomings and sins: the lack of productive genius in art and literature, the neglect of the moral teachings of religion and philosophy, the slowness to abandon outdated political conceptions, like national sovereignty. Yet we are all involved in this tragedy, and the instinct of self-preservation, the love of our children, makes us think about the way of salvation.

" There are the two political colossi, U.S.A. and U.S.S.R., both pretending to aim at nothing but peace, but both rearming with all their power to defend their ideology and way of life, and between them is a weak and divided Europe, trying to steer a middle course. Both sides are greedily devouring the latest achievements of scientific technology for their armed forces. Both have some kind of theory for their way of life in which they believe with an amazing fanaticism. Yet the foundations of these theories are rather doubtful. They use the same words for different or even opposite ideas, as for instance " democracy," which in the west means a system of parliamentary representation freely and secretly elected, but in the East means something quite different and hard to formulate (a complicated economic and political pyramid of bureaucracy which aims at representing, and working for, ' the people '). In other ways the American theory is much vaguer than the Russian, and that seems to have a historical reason. America has grown by expansion in a practical vacuum; the pioneers of the West had to overcome terrific natural obstacles, but negligible human resistance. The Russia of to-day had to conquer not only natural but human difficulties: she had to break up the rotten system of the Czars and to assimilate backward Asiatic tribes; now she has set herself the task of bringing her brand of modernization to the ancient civilizations of the Far East. For this purpose it is indispensable to have a well-defined doctrine full of slogans, which appeals to the needs and instincts of the poverty-stricken masses. Thus one understands the power which Marx's philosophy has gained in the East. What can we scientists do in this conflict ? We can join the spiritual, religious, philosophical forces, which reject war on ethical grounds. We can even attack the ideological foundations of the conflict itself For science is not only the basis of technology but also the material for a sound philosophy. And the development of modern physics has enriched our thinking by a new principle of fundamental importance, the idea of complementarity. The fact that in an exact science like physics there are found mutually exclusive and complementary situations which cannot be described by the same concepts but need two kinds of expressions, can be applied to other fields of human activity and thought. Some such applications to biology and psychology were suggested to Niels Bohr. In philosophy there is the ancient and central problem of free will. Any act of willing can be regarded on the one side as a spontaneous process in the conscious mind, on the other as a product of motives depending on past or present impressions from the outside world. If one assumes that the latter are subject to deterministic laws of nature, one has a conflict between the feeling of freedom of action and the necessity of a natural process. But if one regards this as an example of complementarity the apparent contradiction turns out to be nothing but an epistemological error. This is a healthy way of thinking, which properly applied may remove many violent disputes not only in philosophy but in all ways of life: for instance in politics.

" Marxian philosophy, which is a hundred years old, knows of course nothing of this new principle. However, a prominent Russian scientist has recently attempted to interpret it from the standpoint of ' dialectic materialism,' which teaches that all thinking consists of a thesis opposed by an antithesis ; after some struggle, they are combined in a synthesis. In this Marxian dogma, so he claims, you have the prediction of what has happened in physics, for instance in optics: Newton's thesis that light consists of particles was opposed by Huygens' antithesis that it consists of waves, until both were united in the synthesis of quantum mechanics. That is all very well and indisputable, though a little trivial. But why not go further and apply it to the two competing ideologies: Liberalism (or Capitalism) and Communism, as thesis and antithesis ? Then one would expect a synthesis of some kind, instead of the Marxian doctrine of the complete and permanent victory of communism. It can hardly be expected that the ideas of Marx, developed about 100 years ago, can throw much light on the development of modern science. The opposite is more likely: that the new philosophical ideas developed by science during these 100 years may help towards a deeper understanding of social and political relations. Indeed, we find two systems of thought which deal with the same structure, the state, in completely different, apparently contradictory ways. One starts from the freedom of the individual as the basic conception, the other from the collective interest of the community.

" This distinction corresponds roughly to the two aspects of the problem of willing which we have just mentioned: the subjective feeling of freedom on the one hand, the causal chain of motives on the other. Thus the West idealizes political and economical liberalism, the East collective life regulated by an all-powerful state. But as it seems likely that the contradiction in the problem of free will can be solved by applying the idea of complementarity, the same will hold for the contradiction of political ideologies. Thus the intellectual gulf between West and East may be bridged, and that is the service which natural philosophy can offer in the present crisis.

" The world which is so ready to use the gifts of science for mass destruction would do well to listen to this message of reconciliation and co-operation."

Max Born
(*Physics in my Generation*)

2. Write an essay on one of the following subjects :—

Fashion in Men's Clothes
The British Climate
" Is Britain Christian ? "
Professional Football
Technological Education

3. What do you know of (*a*) the Pilgrim Fathers, (*b*) Jacobites, (*c*) Chartists, (*d*) the Tolpuddle martyrs, and (*e*) suffragettes ?

4. Discuss :

EITHER (*a*) " Physicists . . . tend to speak a strange language of their own, much of which they understand." (*Stephen White*).

OR (*b*) " In our own day it would not be an unfair description of education to define it as the art which teaches men to be deceived by the printed word." (*Harold Laski*).

5. What are the Nobel prizes and for what subjects are they awarded ? For what achievements were prizes awarded to Sir Winston Churchill, Albert Schweitzer, T. S. Eliot, Sir John Cockcroft and the Society of Friends ?

6. Give appropriate entries (of 50-100 words each) for four of the following journals in a handbook intended to acquaint a foreign visitor with the British Press :—

Punch, Spectator, New Statesman and Nation, Tribune, Listener, Economist.

7. Who, in your opinion, were the three greatest Presidents of the United States of America ? Discuss briefly the problems that each had to face or give other evidence to support your choice.

COMMENTS BY THE EXAMINERS

Physics I — Professor J. D. Craggs

Eighty-three candidates answered this paper. The failure rate was relatively low, but this does not accurately reflect the generally low standard of the scripts. Too many candidates answered discrete parts of the questions without making any effort to cope with the other part of the same questions. Indeed, the general impression gained was that the majority of candidates did not possess, nor have any great thirst for, a reasonably detailed knowledge over the whole syllabus. It would appear, perhaps because of lack of time, that candidates do very little general reading and seem content to deal perfunctorily with many of the topics in the paper.

Q. 1. (56 answers) This question probably was the easiest for most candidates, the majority of whom appeared to have at least a smattering of knowledge about methods of measuring surface tension. Quite frequently extremely elementary mathematics needed was incorrectly given and, as might be expected, very little critical ability was shown in assessing the relative accuracy of the different methods.

Q. 2. (58 answers) This question was set partly because of its topical interest but in nearly every case candidates appear to be unaware of the post-war work in this field and limited themselves to classical textbook examples. However there were some good answers and the general level was not too unsatisfactory.

Q. 3. (60 answers) Questions of this type are perhaps tempting to students who do not really understand the basic physics. It was not to be expected indeed that many of them would be able to answer the first part of the question with any authority but again the subject is of such widespread importance that I regarded it as a fair one. The second part of the question, which should be answered by any candidate with a sound knowledge of techniques, was, if anything, more incompetently dealt with than the first part and too much attention in general was given to trivial points with little emphasis on the important aspects of dynamic vacuum systems, e.g. pumping speeds, etc. It is possible that the general standard of the answers reflects the paucity of really good books on this subject.

Q. 4. (60 answers) The purpose of this question was to give students the opportunity of demonstrating their detailed knowledge of the relevance of the Doppler effect in spectroscopy, radar systems, etc. There were a few good answers but generally again the candidates showed only a cursory daily newspaper knowledge of the wider applications.

Q. 5. (18 answers) Although this topic is not specifically mentioned in the syllabus, the purpose of this question again was to allow students to show their knowledge of an important branch of technical physics in which notable advances have been made during the last few years. It is most unfortunate that anyone seriously presenting himself for the Graduateship examination should not have read something of the work of Bowden and his collaborators. In fact, a few candidates showed nodding acquaintance with this work but most of the essays were very trivial. In an examination of this standard an account of "A" level work on bodies sliding down inclined planes is not acceptable.

Q. 6. (52 answers) Again there were a few good answers but the general level of the scripts indicated again a pre-occupation with perhaps somewhat old-fashioned textbook work.

Q. 7. (5 answers) This question was answered least well of all those set, rather to my surprise, since any student of modern acoustical methods should have a fairly full knowledge of the Rayleigh disc even though admittedly it may not be widely used in practice. There were no good answers to the question at all.

Q. 8. (55 answers) This question was answered fairly well although, as in the case of Question 3, the tendency was to pad out a little knowledge in unconvincing attempts to demonstrate wider reading of a qualitative nature. There were several good answers.

Physics II — Professor H. Lipson

Although well over half the 79 candidates failed in this paper, there were some heartening signs of improvement over previous years. There were very few absurd errors; there were some quite valiant attempts at unusual problems ; and some of the failures seem to be caused by bad planning—over-indulgence in a favourite theme, for example. Detailed comments on the answers are as follows :—

Q. 1. (31 answers) Most candidates were not clear that an equation of state attempts to take into account changes of state. The problem, on a hypothetical equation, served well to sort out the candidates : a level-headed attack soon brought quick results, even if not a complete solution ; but many tied themselves up with mathematics, without any clear objective. Some even produced values of the a's that were not constant, and very few noticed that a_0 must be zero.

Q. 2. (45 answers) Too many candidates plunged straight into mathematical manipulation, whereas the question clearly asked for a physical interpretation of internal energy. Some candidates gave the impression that they had just revised the subject and wanted to put the formulae down before they forgot them ! The description of the porous-plug experiment was, on the whole, good, but the physical approach again was lacking.

Q. 3. (46 answers) There were many creditable attempts on this problem, which involved heat conduction across a solid of which one face was not at a constant temperature. Those who recognized this fact made commendable attempts to introduce simplifying assumptions and credit was given for these even if the examiner did not agree with them completely. (See this *Bulletin*, February 1959, p. 38).

Q. 4. (33 answers) Again, there was too much emphasis on formulae and equations in discussing free energy and very few candidates made reasonable attempts at discussing the use of the free-energy concept in the study of equilibrium. The bookwork, however, was very well done.

Q. 5. (43 answers) Stefan's law was universally known, but few could define his constant properly. The experimental work was either known or not known and the question was not a good one for sorting out the candidates.

Q. 6. (24 answers) Most candidates knew the principle of operation of the fluorescent lamp, and some knew a great deal more about its technical mysteries than did the examiner. (See this *Bulletin*, May 1959, p. 128). Many made commendable efforts to solve the problem, some of them successfully.

Q. 7. (51 answers) Spherical aberration and coma were well known and described. Few candidates, however, were well informed about methods of eliminating spherical aberration ; few mentioned the Schmidt plate, and none knew the theory of it.

Q. 8. (37 answers) The description of the passage of light through a biaxial crystal was generally at a low—almost a schoolboy—level. Only five candidates made a satisfactory attempt at the problem.

Q. 9. (34 answers) Although the measurement of the velocity of electromagnetic radiation was asked for, most candidates concentrated upon light, again at too elementary a level ; Essen's recent work does not appear to be well known. Evaluation of the impact of the measurement on physical theory was poor ; $E=mc^2$ was usually the only topic mentioned but, after all, the most significant effect of this equation arises simply from the fact that c is large !

Physics III — Professor J. D. Craggs

Twenty-one candidates intended to present themselves for this examination but no less than ten were marked absent. The small number of scripts thereby resulting follows the pattern of previous years, deplorable though it is. The general standard of the scripts was extremely low, and indeed only two of them can be regarded as satisfactory.

Q. 1. (6 answers) Although it can be objected that this is a specialized question the syllabus covers discharges in gases and its present importance need not be stressed. It was quite clear that not a single one of the candidates really knew anything about arcs.

Q. 2. (7 answers) This, with question 3, probably provided the best answers, but again there seems no reason why every candidate for an examination of this kind should not be able to answer a question on electrical power factors in considerable detail.

Q. 3. (9 answers) This question was also answered reasonably well although it may perhaps be taken to indicate an unhealthy preoccupation with classical electrostatics and it may well be that elementary textbooks are to blame, things being as they are.

Q. 4. (6 answers) There were two tolerable answers and the remaining candidates clearly had no ideas about electronic circuits, ancient or modern.

Q. 5. (4 answers) Three out of four answers were very good although since the subject matter is of basic importance to those studying magnetism many more candidates should have attempted the question.

Q. 6. (5 answers) All the answers were poor and not a single candidate showed familiarity with the Schering bridge or the Kelvin bridge, both of them of importance to students of electrical measurements.

Q. 7. (7 answers) This was allowable on the syllabus, although it may seem out of place, to outside observers. It was particularly an effort to be charitable in case charity were needed. Despite this, and the way in which nuclear fission and its consequences are affecting our daily lives only one student really seemed to have much idea of the subject. There were confusions about the meaning of the question, simple as it is, and candidates tended to write an essay (diffuse and unsatisfactory) on nuclear physics in general. This was where charity finally appeared.

Q. 8. (3 answers) All these answers were reasonably good, although none could be described as first class.

More Advanced Physics — Professor H. Lipson

It may be that this paper was too straightforward, but many of the answers were extremely good, and two-thirds of the candidates passed. The main general fault was that answers were often too long ; students could well learn to write more concisely and to avoid padding.

Q. 1. (8 answers) Was very poorly done. Most candidates, rather surprisingly, did not know what was meant by two-dimensional diffraction ; little was known about single-crystal X-ray goniometers ; and all attempts at the very simple problem were pathetic.

Q. 2. (4 answers) On multiple-beam interference, was also poorly done, but the number of answers was too small for any generalization.

Q. 3. (22 answers) Was most encouraging. Candidates were well acquainted with the principles of the various particle accelerators, although they were not quite clear about their relative functions. In addition, few mentioned the fact that some machines work in pulses.

Q. 4. (22 answers) The methods of emission of electrons from matter were well known, and descriptions of their experimental investigation, although not always sufficiently detailed, were on the whole satisfactory.

Q. 5. (17 answers) Theories of electrical conduction in metals and semiconductors were adequately described to the standard expected in this examination. Some of the descriptions of the action of transistors were excellent, but the examiner was disappointed that no candidate thought of including a typical circuit.

Q. 6. (20 answers) Most candidates knew how the continuous X-ray spectrum was produced and could derive the expression for the minimum wavelength. Bur few appreciated the technical difficulties, of voltage regulation and measurement for example, that could be involved in verifying this expression precisely.

Q. 7. (22 answers) The Michelson-Morley experiment was well described and explained, and its importance in physical theory was well understood.

Applied Physics — Mr. A. E. De Barr

Very few of the answers given reached a level appropriate to a Graduateship examination. Candidates should realize that, although they may be answering questions which could be asked in National Certificate or G.C.E. examinations, a different kind of answer is expected.

Electronics — Mr. A. E. De Barr

In general, the answers this year were appreciably less satisfactory than in previous years, and only a few candidates showed any ability to tackle numerical examples.

Q. 1. No one aspiring to graduate standard in electronics could object to being expected to perform the five simple calculations asked for in this compulsory question, yet only 24 correct solutions were obtained out of a possible 135 ! That the average mark given was nearly 8 (out of 20) is merely evidence of the leniency of the marking.

Q. 2. Most candidates knew a little about the significance of the Fermi level but only a few made any attempt to explain the origin of the work function.

Q. 3. The answers to this question were chiefly notable for the presence of a great deal of unnecessary algebra and the absence of any physical explanation.

Q. 4. The descriptive parts of this question were moderately well answered but only one correct value for the threshold wavelength was obtained, and there were no correct answers to the remainder of the question.

Q. 5. Here too, candidates tried to rely on algebra to disguise their ignorance of physical principles and very few knew of a fourth type of oscillator. Surprisingly, no correct answer was given to the numerical part of the question.

Q. 6. The first part was fairly well answered but there were no reasonable answers to the second part. Whilst candidates are not expected to be able to discuss this relation fully, they should at least have some inkling of the reasons for the limitations it imposes.

Q. 7. This was the only question for which the average mark obtained was appreciably different from 8 ± 1 (out of 20) : for this question the average mark was less than 6. Answers to questions involving impedance in previous years have suggested that the subject is imperfectly understood by many candidates, and led to the decision to devote a full question to the subject. Whilst some candidates could deal with the impedances of a simple triode amplifier circuit, the presence of the cathode resistor proved too much for most. It is quite obvious from the answers to this question that few candidates have ever been shown a general method of calculating input and output impedances.

Q. 8. Most candidates would answer the first part of the question, but it was rather surprising that, with " Hi-Fi " so much in evidence to-day, the answers to the second and numerical sections were poor. No correct answers were given to the last part of the question.

Q. 9. Although candidates knew something of the functions of the three devices mentioned, they seemed to have difficulty in linking-up their operation with an account of the conduction of electricity in gases. In addition, most seemed very vague about alternative ways of performing the operations.

Statistics — Mr. E. D. van Rest

Three candidates took the Statistics paper ; only one reached a pass standard.

Of the four answers required in this paper at least one must be from those requiring rather lengthy calculation. Judging by the answers to the remaining questions it appears that a disproportionate amount of time is spent on these calculations. It would be unrealistic to set a paper without the sums which form such a large part of statistical methods so that it would seem that more practice and instruction need to be given in short methods and rapid and accurate calculation of the simple sums involved.

It is also clear that students need practice in expressing the basic statistical ideas in words ; such exercises would serve to reveal misconceptions about those ideas. Students should also be given practice in writing accounts of the statistical attack made on problems in order that they may be able to explain why one technique is used in preference to another.

Mathematics I and II — Dr. A. W. Gillies

This year more candidates took these papers, but the number of passes was no greater than in previous years. It would appear that the increase was formed by candidates who were not up to the standard required by the Institute.

On paper I all candidates tried Question 1, but none knew how to do the second part properly, and some did not know what was meant by " product of factors."

In Question 2 no one could explain clearly the criterion for a minimum even on a purely graphical basis ; and although here, as in most cases, this criterion is the easiest to apply, most candidates in the second part of the question rejected it in favour of working out a rather clumsy second differential coefficient, if they worried at all beyond the stationary value. The last part of the question baffled everyone, though a random set of values would have a fair chance of satisfying the requirements.

No candidate could cope with the Fourier series in complex form, or with the use of complex numbers to represent simple periodic function in Question 9.

There was one good solution to Question 8 and two to Question 5. Several others who tried Question 5 had no idea whatever on solid analytical geometry, and those who tried Question 10 could not reproduce the bookwork successfully.

In paper II, no candidate attempted Question 10. In Question 6, the occurrence of x in the upper limit of the integral was ignored, and even the simple resisted motion question produced only three good solutions.

General Paper — Mr. N. Clarke

The entry of twenty-two candidates was the largest since the examination began ; without enthusiasm and with charity I was able to pass four candidates. The standard I demand is not high and I should expect a boy or girl of average ability in the science Sixth of a good grammar school to score high marks and to pass with ease.* Considering that the average age of the present candidates was 24 years and that I was prepared to take account of the comparative youthfulness of the four candidates under the age of twenty, the performance on this paper was appallingly low. Most candidates could spell tolerably well and their English style showed less evidence of *Daily Sketch* journalese than has often been apparent. Few candidates, however, displayed more than superficial knowledge of the world in which they live, and it is depressing to find men of almost thirty betraying an ignorance and a naïvety that one would not expect to find in a well-educated child of sixteen.

It is difficult to know how far one should penalize bad spelling and punctuation which falls outside the bounds of reasonable difference of opinion. Perhaps wrongly I try to be tolerant, but there are limits beyond which my tolerance will not go. For example, one candidate aged twenty-four, whose general knowledge appeared to be considerably better than that of most other candidates, produced a script of which the following is a fairly typical example :—

> " The suffragettes, where mainly women, though a large number of men supported then, at the beginning of the century who's belief was equallity for women, to support this the demand was a parliementry vote for womens
>
> This lead to there cry " Vote's for Women."
>
> Various attemps were made to bring the grievences to the public and the attension of the House of Commons usually by chaining themselves to railing outside parliament or by braking windows in the houses of pronint people.
>
> These came to a head when one suffragette was killed when she through herself in front of the Kings horse during the Derby of one year, because of this and the persistance with which the general campain was organised, women were eventually given the vote."

I refuse to accept this as evidence of suitability for professional status and I find it difficult to understand how such a candidate has been able to secure a Higher National Certificate, the rules for which state that " English is not a subject in the course but students will be required to express themselves clearly and precisely."

The following are comments on individual questions.

Q. 1. (22 answers) Candidates taking this examination always seem to find this kind of question (which perhaps makes least demand on creative thought) much easier than any other. On the whole the answers were quite reasonable and two were fairly good. There were some quaint transcriptions of Polanyi's thoughts, and I rather liked " we in Europe are sitting in the middle of much troubled waters and in a situation like this it is becoming increasingly difficult to remain in the middle."

Q. 2. (22 answers) Our climate was the favourite subject, with six answers. Fashion and football each had five, Christianity four and education two. The general standard was very poor but there was one quite good essay on professional football from a candidate whom I passed although he attempted only three questions. One London candidate described the North of England as cold because it was close to the Arctic circle and " due to the great stony mountains which are covered with snow eight months in the year." Another candidate considered that " professional football has become an Industry of England, like Woolworths."

Q. 3. (9 answers) Most candidates had heard of the suffragettes, although one wrote that they demonstrated " against what they called women sufferage." As another candidate said, " the result was an all-out win for the ladies." The Pilgrim Farthers (*sic*) were described as having discovered America one hundred years ago.

Q. 4. (15 answers) It was perhaps surprising to find that this question was the most popular one of those from which a choice could be made. Almost everything that was written was rubbish.

Q. 5. (11 answers) There was one good answer and several fair attempts. T. S. Elliott, however, was stated to have received the Nobel prize " for his help to science in the form of drugs and chemistry " while Sir John Cockcroft's name meant so much to one budding physicist that he wrote " Sir John Cockcroft and his society of friends were awarded the prize for literature and writing." Another candidate ventured the information that the Society of Friends had not been so active since the National Health Service became available.

Q. 6. (5 answers) There was one good answer.

Q. 7. (9 answers) Two of the candidates who attempted this question could mention only one President, George Washington. Of the seven who did select three Presidents, six included Lincoln, six Truman, five Roosevelt, two Eisenhower, one Wilson and one Washington.

Practical Physics — Mr. A. E. De Barr and Mr. J. Yarwood

The examination was conducted as in previous years and candidates had to do two experiments : a simple one (questions 1, 2, 3 or 4) and a more elaborate one.

It is gratifying to be able to report that questions 1, 2 and 4 were fairly well done and some candidates even obtained the correct answers ! Those candidates who were set question 3, however, had to be shown how to obtain a bridge that could be balanced.

Whilst candidates were not expected to be familiar with the more complicated experiments of the second part of the examination, they were expected to have some slight acquaintance with, for example, vacuum pumps, Pirani gauges, Geiger counters. It would seem as if the practical training of many candidates has been restricted to the use of the teaching apparatus of pre-war years, and such candidates are inevitably at a disadvantage when called upon to use more modern equipment, even when some instruction is given.

On the whole, candidates' written accounts of their experiments were appreciably better than in previous years, although there is still room for improvement.

---

* Though the co-operation of Miss K. E. Parks (*Associate*) I have been able to make an interesting comparison ; a group of girls aged sixteen or seventeen on the science side of the North London Collegiate School have also taken this paper, without preparation. Their performance was incomparably better than that of the Graduateship candidates and amply bears out my comment.

CENTRAL ELECTRICITY GENERATING BOARD

RESEARCH AND DEVELOPMENT DEPARTMENT

OPERATIONS BRANCH

AT HEADQUARTERS, LONDON, S.E.1. REF. BP/343.

Applications are invited for an appointment as **ENGINEER** or **PHYSICIST** (**ELECTRICAL**) in the above department.

The successful candidate will be required to work in a small team dealing with a wide range of electrical problems associated with the operation of generating and transmission equipment. This will involve visits to power stations and other sites and close contact with relevant research within and outside the industry. Initially the post will provide experience over a wide field, but there will be opportunities to specialize later.

A good University Degree, or membership of The Institute of Physics is required. Experience in the industry or of research work would be an advantage, but new graduates would be considered if of the right calibre.

The salary will be on a scale within a range rising to £1,350 p.a., according to duties and responsibilities. Opportunities for promotion in an expanding organization are good.

GENERATION SECTION

AT THE RESEARCH LABORATORIES, LEATHERHEAD, SURREY. Ref. BP/330.

ENGINEER or **PHYSICIST** required to take charge of a small team working on basic research into the mechanism of Mechanical Seals for use in large boiler feed-pumps and high pressure gas circulators.

Applicants should possess an honours degree or Membership of the Institute of Physics, and have a sound knowledge of **fluid dynamics.** Previous research experience is essential although this need not necessarily have been in this particular field.

Salary within the range £1,195—£1,775 p.a., according to duties and responsibilities.

Applications stating age, qualifications, experience, present position and salary, to the Personnel Officer, 24/30 Holborn, London, E.C.1, by September 7, 1959. Envelopes should be marked "Confidential" quoting relevant reference number.

JOSEPH LUCAS LTD.

GROUP RESEARCH CENTRE

◆ ◆ ◆

Applications are invited for the following posts in research teams which are investigating physical-chemical and electro-chemical processes related to the Company's present and future products. A wide range of the most modern facilities and equipment is available in the Group Research Centre at Marston Green, Birmingham.

PHYSICAL CHEMIST with honours degree to carry out research in the above field using X-ray diffraction and optical microscopy techniques. Experience of X-ray work would be an advantage.

PHYSICAL CHEMIST with degree or similar qualification to undertake research on electro-chemical problems, with particular reference to electrode processes.

CHEMIST with degree or similar qualification to undertake research on the chemical reactions and physical processes occurring in battery plates during use. A knowledge of vacuum and gas-handling techniques would be an advantage.

CHEMIST of H.N.C. standard to undertake research on electro-chemical problems, with particular reference to investigations on new types of battery.

LABORATORY ASSISTANT of O.N.C. or G.C.E. (O) level to undertake routine experimental work, and to assist with one of the research projects.

The posts are permanent and pensionable and good starting salaries will be paid according to experience. Apply in writing giving full details of age, qualifications and experience to the

Personnel Manager
Joseph Lucas (Electrical) Ltd.
Great King Street
Birmingham, 19

quoting reference PM/GR/282.

WARWICKSHIRE EDUCATION COMMITTEE

RUGBY COLLEGE OF ENGINEERING TECHNOLOGY

DEPARTMENT OF SCIENCE AND MATHEMATICS

Applications are invited for a post as SENIOR LECTURER in Physical Science. The position requires a well-qualified Physicist with an interest in materials. Applicants should have teaching and research experience. Industrial experience involving work in some aspect of solid state physics would be a valuable qualification. Teaching duties would be in full-time sandwich courses preparing students for degrees in engineering, the diploma in technology and professional examinations. The successful candidate would be expected to take a substantial part in a research program involving fundamental work in the science of materials.

Salary in accordance with the Burnham Technical Report. Senior Lecturer: £1,550 × £50 - £1,750. Further particulars and application forms may be obtained from the Principal, Rugby College of Engineering Technology, Eastlands, Rugby, to whom applications should be sent as soon as possible. N. A. Y. Yorke-Lodge, County Education Officer, County Education Office, 22 Northgate Street, Warwick.

A SPECTROSCOPIST

is required at the Atomic Energy Research Establishment, Harwell, to assist in the development of spectroscopic techniques applied to the study of atomic spectra in the transuranic elements. There is ample opportunity to take part in research work of a non-routine nature in a well-equipped general spectroscopy group. Applicants should have G.C.E. at " A " level, H.N.C. or equivalent. A pass degree (including physics or chemistry) and a practical or theoretical knowledge of spectroscopic techniques would be an advantage. Salary £540 (at age 21)—£1,260 according to age and experience. Housing and superannuation schemes.

Please send a postcard for details to the Group Recruitment Officer (5047/110), U.K.A.E.A., A.E.R.E., Harwell, Berks.

UNIVERSITY OF OTAGO

DUNEDIN, NEW ZEALAND

SENIOR LECTURER OR LECTURER IN PHYSICS

Applications are invited for this position. It is hoped to make the appointment at the Lecturer level (salary £1,025 × £50 - £1,275 per annum) but an appointment would be possible at the Senior Lecturer level (salary £1,315 × £50 - £1,615 per annum) if a suitably qualified applicant was available. Further particulars are available from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in New Zealand and London on November 30, 1959.

ENGLISH ELECTRIC VALVE COMPANY LTD.

CHELMSFORD, ESSEX

◆

Fundamental Research into Photoconductivity and allied fields

◆

Applications are invited from PHYSICISTS with a higher degree or a good honours degree. Preference will be given to candidates with research experience in photoconductivity or in other branches of solid state physics or semiconductors. Starting salary will take into account relevant experience.

Applications, giving full details of experience and qualifications, should be sent to Dept. C.P.S., Marconi House, 336/7 Strand, London, W.C.2, quoting reference 1513G.

TEXTILE CHEMISTS AND PHYSICISTS

Vacancies exist for YOUNG SCIENTISTS in a new Research Department. The work will cover a wide field of textile interests including synthetic fibres, sewing threads, and bulked yarns

A good degree in Physics or Chemistry is desirable and for one of the posts a few years' research experience in the physics of textiles is necessary.

This is a good opportunity for keen young men to assist in the development of a new section and consideration will be given to graduates who may shortly return from National Service.

Good terms of Employment. Pension Scheme.

Write for special forms of application to :

Chief Personnel Officer,
English Sewing Cotton Company Ltd.,
Arkwright House, Manchester, 3.

AUSTRALIA

THE UNIVERSITY OF NEW SOUTH WALES

ACADEMIC VACANCIES

SCHOOL OF APPLIED PHYSICS

The University of New South Wales invites applications for appointment as Teaching Fellows in its School of Applied Physics. Salary: £A1,016 range £A1,216 per annum. Commencing salary according to qualifications and experience. Applicatns should possess a degree preferably with honours or equivalent qualifications. Initial appointment is for two years and there are prospects of re-engagement for a further year. Successful applicants will enrol for a higher degree and undertake a limited amount of teaching duties. The research activities and equipment of the School chiefly relate to: X-ray analysis, dielectrics, magnetism (including NMR) vacuum physics, applied optics (including solar furnaces). Appointees will be nominated for travel to Australia under the Assisted Passage Scheme. Four copies of applications, together with the names of three referees, should be lodged with the Agent General for New South Wales, 56 Strand, London, W.C.2, and a copy forwarded by airmail in an envelope marked "University Appointment" to the Bursar, The University of New South Wales, Post Office, Box 1, Kensington, New South Wales, Australia, before September 30, 1959.

South Manchester H.M.C., Christie Hospital and Holt Radium Institute, Manchester, 20. There is a vacancy for a PHYSICIST (Basic Grade) in the Clinical Physics department at the above hospital. Since the equipment of the hospital includes a 20 MeV Betatron, a 4 MeV Linear Accelerator and a 2000 curie Cobalt-60 unit, as well as the normal complement of conventional X-ray machines, radium and other radioactive isotopes, post offers unrivalled opportunities of experience in radiotherapy physics. Opportunities for research are available, and of some teaching if desired. Salary, according to Whitley Council scale, is within the range £570 – £1,035. Applications, giving the names of two referees should be made to the Hospital Secretary, as soon as possible.

G. V. Planer Ltd., Consultants and Research Laboratories, have two new high level research vacancies on important Ministry and industrial projects:

Semiconductors: **PHYSICIST OR CHEMIST** with specialized experience in the fields of semiconducting materials and/or devices.

Electrical Ceramics: **A CERAMICIST, PHYSICIST OR CHEMIST** with experience in one or more of the fields of titanate dielectrics, piezo-electric ceramics or ferrites. Both appointments are highly progressive and carry attractive salaries in accordance with experience and qualifications. Apply in confidence: Dr. G. V. Planer, G. V. Planer Ltd., Windmill Road, Sunbury-on-Thames, Middlesex.

UNIVERSITY OF OTAGO

DUNEDIN, NEW ZEALAND

SENIOR LECTURER OR LECTURER IN STATISTICS

Applications are invited for this position. Salary range: Senior Lecturer £1,315 × £50 – £1,615; Lecturer £1,025 × £50 – £1,275 per annum. Further particulars are available from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1, or from the Registrar, University of Otago, Dunedin, New Zealand.

Applications close, in New Zealand and London, on October 15, 1959.

UNIVERSITY OF SYDNEY

LECTURESHIP/SENIOR LECTURESHIP IN MATHEMATICAL STATISTICS

Applications are invited for the above position. The salary for a Senior Lecturer is within the range £A2,200 × £80 – £2,600 per annum; for a Lecturer within the range £A1,500 × £90 – £2,100 per annum, and will be subject to deductions under the State Superannuation Act. In each case cost of living adjustment will be allowed. The commencing salary will be fixed according to the qualifications and experience of the successful applicant. Under the Staff Members' Housing Scheme, in cases approved by the University and its Bankers, married men may be assisted by loans to purchase a house. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in Australia and London, on October 3, 1959.

APPLIED CHEMISTS AND PHYSICISTS

British Nylon Spinners Ltd. invite applications for vacancies caused by the extension of their Research and Development activities at their Pontypool headquarters. Those men who have not only a good academic qualification in chemistry or physics and, for preference, some postgraduate experience but also have a desire to use their training and see their energies directed to obviously useful ends, should find the work of unusual interest. The objectives can only be properly pursued in co-operation with commercial staff and with other industries, and therefore there will be plenty of opportunity for the exercise of personal qualities and for the demonstration of initiative and willingness to accept responsibility. Conditions of employment are attractive and in line with the best available in industry to-day, and the Company's premises are in unexpectedly delightful countryside in a rural area, with good communications providing the best of town, sea and country. Housing presents little real difficulty, and the Company gives considerable assistance to new staff in resettling their families. Applications should be addressed to the Personnel Manager, British Nylon Spinners Ltd., Pontypool, Monmouthshire.

MINISTRY OF SUPPLY: INDUSTRIAL CHEMISTS. 10 pensionable posts for men and women at least 23 and under 35 on September 1, 1959; extension for regular Forces service, H.M. Overseas Civil Service, established civil service, and temporary service as Industrial Chemist. Candidates must normally have honours degree in metallurgy, engineering, chemistry, physics, or chemical engineering, or have achieved Associateship *or* Graduate Membership of Royal Institute of Chemistry, Associateship of Institution of Metallurgists or Institute of Physics, or Corporate Membership of Institution of Chemical Engineers. Starting salary (men, London) from £690 to £1,125 according to age. Scale maximum £1,300. Promotion prospects. Write Civil Service Commission, 17 North Audley Street, London, W.1, for application forms, quoting S 5007/59.

BTH GROUP RESEARCH LABORATORY, RUGBY

Vacancies exist in the Machining Group for PHYSICISTS, ENGINEERS and MATHEMATICIANS with honours degree. They are required to conduct research in the following fields: (*a*) mechanism of cutting tool wear and failure, (*b*) mechanics of continuous and interrupted cutting, (*c*) operational research into the use and performance of practical cutting tools. The Group in general does work designed to meet the requirements of all factories under BTH Group Management, and there is a wide and expanding field of research, giving considerable scope for individual initiative. Applicants, who should be free from National Service obligation, are invited to write to the Director of Research, British Thomson-Houston Co. Ltd., Research Laboratory, Rugby, giving details of education, experience and qualifications, and to quote reference TJ.

D.S.I.R. NEW ZEALAND

DOMINION PHYSICAL LABORATORY

SENIOR PRINCIPAL SCIENTIFIC OFFICER

VACANCY 424

Salary up to £1,860 a year according to qualifications and experience. Duties: To take charge of the electrical division of the Dominion Physical Laboratory, including the very flourishing Auroral Station at Invercargill, which co-ordinates the auroral program at Scott Base. Other subjects are V.L.F. propagation, whistlers, forward scatter, acoustics, electric standards and the encouragement of local industry. Staff includes 12 professional and 33 technical officers and technicians.

Sea passages to New Zealand for appointees and their families will be arranged and paid for by the department. In addition an allowance will be made towards the cost of transporting light personal effects. Enquiries, mentioning this publication and quoting Reference No. B11/21/14, should be addressed to the High Commissioner for New Zealand, 415 Strand, London, W.C.2. Completed applications to be lodged in London not later than October 14, 1959.

PRINTED BY F. J. MILNER AND SONS LIMITED, COMMERCE ROAD, BRENTFORD, MIDDX.

BP invites applications from GRADUATES aged 23-26 years with an honours degree in Petroleum engineering, engineering or physics for employment as Petroleum engineers in Trinidad in the first instance. Duties will consist of assisting in all aspects of field production work, including well control, artificial lift, gas control, oil collection and well servicing. National Service obligations must have been fulfilled. Write, stating age and full details of qualifications and experience, quoting F.574, to The Manager, Recruitment Branch, The British Petroleum Company Limited, BP House, Ropemaker Street, London, E.C.2.

THE BRITISH BOOT, SHOE AND ALLIED TRADES RESEARCH ASSOCIATION

has the following vacancies for young scientists. Specialized knowledge of shoe industry is not expected.

PHYSICIST for work on shoe materials of all kinds, with reference to their behaviour in shoe manufacturing processes and to their durability and comfort in wear. Qualification : a good degree in physics. Consideration will also be given to graduates in physical chemistry and to mathematicians desiring to change to practical work. Some experience of research or development work an advantage.

SECTION LEADER FOR PHYSICAL TESTING DEPARTMENT, which tests most of the new materials that are continually coming into use in the industry. This work is of great importance as the industry buys materials worth about £100 million per annum. The position is a responsible one involving frequent personal contacts with members, including specialists in many fields. Qualifications : Graduate preferred. Non-graduates of proved ability and with relevant training and experience will also be considered.

The salaries and prospects offered will attract good men and there are generous superannuation schemes. Details gladly sent. Write giving personal particulars to : Director, Satra House, Rockingham Road, Kettering, Northants.

THE UNIVERSITY OF MANCHESTER

Applications are invited for the post of **READER OR SENIOR LECTURER** in the Department of Physics of the Faculty of Science. Candidates should have experience in experimental physics. Experience in some aspects of applied physics should be particularly valuable. The successful candidate will be responsible for arranging, in consultation with the Professors of physics and engineering, the teaching of physics to engineers at all levels, and will himself participate in such teaching. Salary scales : Reader, £1,800 to £2,150 per annum ; Senior Lecturer, £1,700 to £2,050 per annum ; with membership of F.S.S.U. and Children's Allowance Scheme. Applications should be sent not later than October 5, 1959, to the Registrar, the University, Manchester 13, from whom further particulars and forms of application may be obtained.

Operational Research, Air Ministry. **SENIOR SCIENTIFIC AND SCIENTIFIC OFFICERS** required in Scientific Adviser's Department. Qualifications 1st or 2nd class honours degree in mathematics, statistics or physical science such as physics, engineering. Honours degree in natural or social science if candidate possesses at least mathematical knowledge at G.C.E. advanced level. Appointments offer great scope and interest to versatile scientists capable of working well with Service officers and of adopting methods suited to Service environment. Work is mainly Operational Research in variety of subjects of concern to R.A.F. including tactics, technical development and logistics and offers Senior Scientific Officer and Scientific Officer entrants valuable experience in principles of Operational Research. Salaries : London Senior Scientific Officer £1,233 to £1,460. Scientific Officer £655 to £1,150. Outside London slightly lower. Salaries for women being raised by stages to men's rates. Forms from M.L.N.S. Technical and Scientific Register (K), 26 King Street, London, S.W.1 (quoting A.163/9A/NB). Closing date September 24, 1959.

BTH GROUP RESEARCH LABORATORY, RUGBY

The Machining Research Group requires two **MECHANICAL ELECTRICAL or PRODUCTION ENGINEERS,** with H.N. Certificate or equivalent, to assist in the following work : (*a*) Design and development of tool force dynamometers ; (*b*) Measurement of cutting tool forces ; (*c*) Laboratory evaluation of practical cutting tools and processes. Applicants, who should be free from National Service obligation, are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Group Research Laboratory, Rugby, giving details of education, experience and qualifications, and to quote reference T.J.

UNIVERSITY OF CANTERBURY

CHRISTCHURCH, NEW ZEALAND

LECTURER IN MATHEMATICS

Applications are invited for the above post. Qualifications in either pure or applied mathematics will be acceptable and the appointee will be expected to engage in research in his own field or to assist with work in the field of rocket ballistics already in progress in the Mathematics Department. The salary attached to the position will be at the rate of £1,025 per annum, rising by annual increments of £50 to £1,275 per annum. Commencing salary in accordance with qualifications and experience. An allowance is made towards travelling expenses. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in New Zealand and London on November 30, 1959.

UNIVERSITY OF SYDNEY

SENIOR TUTOR-DEMONSTRATORSHIP IN PHYSICS

Applications are invited for the position of Senior Tutor-Demonstrator in Physics. The salary for a Senior Tutor-Demonstrator is within the range £1,500 × £90 – £1,770 (Australian) per annum plus cost of living adjustment (at present £A18 p.a.) and will be subject to deductions under the State Superannuation Act. The commencing salary will be fixed according to the qualifications and experience of the successful applicant. He will be expected to be available by March, 1960.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in Australia and London on October 17, 1959.

SPACE RESEARCH : (*a*) SENIOR EXPERIMENTAL OFFICER (minimum age 35) ; and (*b*) **EXPERIMENTAL OFFICER** (minimum age 27) to work under auspices of Royal Society on assembly, installation and testing of space research instruments at R.A.E. Farnborough for use in upper atmosphere research rocket Skylark. Senior post duties involve close co-operation with physicists working in British Universities on space research problems and offer interesting work in this field. Qualifications, H.N.C., H.S.C., G.C.E. (advanced level), pass degree or equivalent. For (*a*) some experience of transistor techniques essential. Experience of missiles and/or telemetry systems an advantage, with good practical knowledge of light electrical engineering and electronic practice, in particular power construction of airborne electronic and electric assemblies with experience in any of following fields : guided weapon guidance and control systems, telemetry, flight instrumentation, airborne radio and/or radar systems. Salary ranges (*a*) £1,315 – £1,560, (*b*) £954 – £1,166. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D 431/9A.

COURSES

SURREY COUNTY COUNCIL

EWELL COUNTY TECHNICAL COLLEGE

A course of 12 weekly lectures on "Transistors and their Applications" will begin on Tuesday, September 22, 1959, at 7.0 p.m. The course will deal with basic semiconductor physics, transistor design and construction, transistor equivalent circuits; circuits using transistors in amplifiers, generators, computers, and power supplies. A knowledge of elementary physics will be assumed. Course fee: £1 2s. 6d. Apply immediately to Head of Science Department, Ewell County Technical College, Ewell, Surrey.